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GEOLOGICAL SURVEY OF LOUISIANA

GILBERT D. HARRIS, Geologist-in-Charge

NOTES ON THE GEOLOGY

OF THE

Winnfield Sheet

BY

G. D. HARRIS

Made Under the Direction of the State Experiment Stations

W. R. DODSON, Director

BATON ROUGE
1907

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TOWNSHIP
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NOTES ON THE GEOLOGY OF THE WINNFIELD SHEET

BY

G. D. HARRIS.

INTRODUCTORY REMARKS.

DESIRABILITY OF GOOD MAPS.

During the past seven years we have been slowly, yet persistently, paving the way to the construction of detailed topographic maps of certain portions, if not all, of the State of Louisiana. And this for the following reasons:

I. Good topographic maps furnish the prospective immigrant or investor the means of judging the character of the area or areas he may have in mind for settlement or financial operations.

II. In sparsely settled areas, good maps are of inestimable value to the traveler along the common highways. They save him the trouble and embarrassment of losing his way.

III. In projecting roads and railroads, a few minutes' study of a reliable map may save thousands of dollars in reconnoissance work.

IV. They furnish the basis whereon the distribution of soils, timber, mineral products and geological formations may be shown.

V. They furnish the basis for detailed studies in Physical Geography in all our more advanced high schools and colleges.

VI. Incidentally good maps serve as an index to the stage of social and financial development of the people ordering their construction.

The State Geological Survey is mainly interested in good maps because on them alone can detailed geologic features be correctly represented. Likewise, the United States Geological Survey has been interested in the construction of such maps, and, a large amount of its annual appropriations has been used for that purpose. The Bureau of Soils of the United States

Agricultural Department has also felt the pressing need of detailed maps and has often been obliged to devote much time and money to the construction of such maps as would serve as a proper basis for showing the distribution of soils.

CO-OPERATIVE MAP WORK.

It is very evident that when any kind of work is carried on by different organizations, State and National, for somewhat different purposes, the results obtained will be of a different kind and of varying general value or accuracy. It seems, therefore, highly desirable that one organization, or one government bureau, should at least set the standard if not actually control the constructional work. Economy demands this. All cannot map the same area to advantage to the State or Nation. In Winn Parish, a part of which forms the subject of the present Bulletin, the State Survey, the United States Geological Survey, and the Soil Survey have each made a substantial contribution towards the final mapping of the region. First the State Survey mapped with detail six townships in the immediate vicinity of Winnfield, townships as a rule known to contain mineral wealth, or points of unusual geologic interest. The topographic map herewith given (Pl. I) indicates the class of work and the area covered. Notice that the scale is the same as that used in the majority of work done by the United States Geological Survey, 1/62,500. The contour interval is also the same (20 feet). Heights are expressed in feet above mean sea level. But that this work might fit into the general scheme of quadrangular 15′ maps published by the United States Geological Survey, the writer suggested to that organization the desirability of accepting such portions of the area shown on Pl. I as could be used in a 15′ area and making such additions laterally as would serve to finish out a sheet of the ordinary standard type. This work is already well under way. The writer also urged the United States Soil Survey to study the distribution of the various soils in this region; the inducement held out to that organization being the detailed completed topographic map of at least six townships in the central portion of the area to be studied. This in turn led the Soil Survey to make further demands on the United States.

Geological Survey to furnish at least an outline map of the whole of Winn Parish, showing roads, streams, houses, though not at present showing contour lines. It is readily seen, then, that in consequence of the initiative taken by the State, the general Government has seen fit to do a large amount of work in this part of the State.

WHY THE WINNFIELD AREA WAS CHOSEN.

In many respects this area is typical of a greater part of the Hill Land of Northern Louisiana. There are many streams dissecting in a remarkable way the land surface, producing many steep, sharp slopes, but no hills as a rule over one hundred feet above the adjacent stream beds. Since, generally, the underlying sand and clay beds lie nearly horizontally, their outcroppings give rise along the gentle hill slopes to soils of varying character. Broad stretches of bottom lands are found adjacent to the larger bayous and rivers showing still different types of soil. The valuable hard wood of the bottoms and the pines of the hill land are disappearing as by magic with the advent of great "company sawmills." Great though the timber wealth of this region may be, calling for new roads and railroads running in every direction from the centers of lumbering activities, finally the soils must furnish the basis for the steady and permanent progress of this section of the country. But the Winnfield area had additional attractions. Here are building stone, limestone for plaster and cement works, salt, and perhaps oil and gas in paying quantities. So it appeared to us that the present mapping of this area might materially assist in the projection of roads and railroads, give information to outside parties as to the surface features of the land, furnish a basis for a careful soil survey of the region and induce the general Government to initiate work of that character here, serve as a basis for geological work now and hereafter, and finally serve the purpose of initiating map work in this part of the State, to be carried on more extensively as time goes on in co-operation with the United States Geological Survey. From what has already been said under "Co-operative map work" and elsewhere it is unnecessary to dwell on the fact that our most sanguine hopes have been more than realized.

TOPOGRAPHY.

FEATURES IN GENERAL.

No one can examine the topographic map herewith published (Pl. I) without being impressed with the smallness of the features exhibited. Or, on the ground, in following any given direction, a section line for example, one is constantly surprised at the great number of small steep slopes encountered. At one moment one finds himself in a narrow step-sided valley, at another on top of a divide, crossing some trail, path, or wagon road of some description, for the roads and trails in their earlier stages of development are almost invariably along the summits of ridges.

Again, one is often surprised at the great width of the bottom lands along the more important watercourses. Swamp conditions are by no means rare.

ELEVATIONS.

It will be observed that the lowest contour is but 80 feet above mean sea level, while in the western part of the map, especially in Sections 20 and 29 of the northwestern township elevations over 300 feet are indicated. In one instance there is a small area over 360 feet above tide. To the north and east elevations are low; to the south and west they are considerably greater. The bottom lands of Dugdemona River, as well as the low swampy plains along the lesser streams, all are very low, when their distance from the Gulf is considered, and especially when it is remembered that the Grand Gulf areas to the south and west have greater altitudes than the area here under discussion.

HISTORY OF TOPOGRAPHIC DEVELOPMENT.

With but very few and minor exceptions the topographic expression of the area under consideration is due to erosion. True it is that fresh exposures along streams and especially along the railways show that the underlying beds have been

uplifted and bent more in some places than in others, faults of a few feet throw can be seen here and there; but, there is no great amount of disparity in the resistance to erosion shown by any of the common sand and clay beds, and hence however complicated the stratigraphy may be the resulting topographic features are almost the same as though the whole country were composed of one great bed of clayey sand.

During Oligocene and Miocene, and doubtless during the greater part of Pliocene times this area was above sea level and was not receiving sedimentation. Doubtless, too, it was somewhat higher in later Tertiary times than now. Erosion went on apace during the later Tertiary, and we suspect some of the broader topographic features to have been outlined before the glacial epoch at the end of the Tertiary. The broad lowlands of the Dugdemona and the subdued and aged features for some distance on either side of the river; the extensive low, swampy bottom lands along such streams as Porte Luce and Cedar Creek, the present tendency of such streams towards aggradation rather than degradation: all show clearly that at some distant period, probably late Tertiary, this region doubtless stood higher above sea level than it does to-day, and hence erosion went on rapidly. Now, however, the country is so low that it is only the uppermost reaches of the streams that are doing erosive work.

There are, as stated above, a few very small areas that do not owe their present appearance to erosion alone. For example, the salt licks, with their light-colored, barren, level, floor-like stretches; the area of the so-called "Marble Quarry," with its sink-holes and recent upheavals; the depression known as Coochie Brake, and the elevation containing the sandstone ledge just to the north of the brake. These topographic features are due, primarily, to upheaving forces from below, or to the dissolving and transporting action of subterranean waters.

GEOLOGY.

MESOZOIC GROUP.

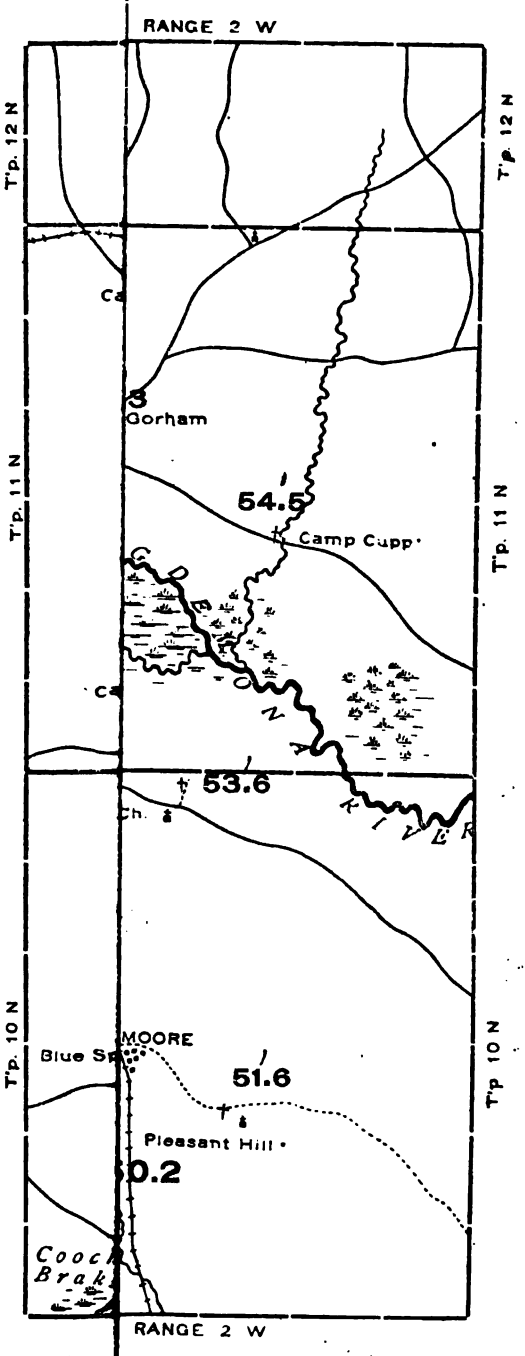
CRETACEOUS SYSTEM.

CRETACEOUS DOMES IN NORTHERN LOUISIANA.

General Remarks.—The earliest references to the Cretaceous rocks about Winnfield, or in the northern part of the State of Louisiana in general, are to be found under "salt licks," "salt works," "salt springs," or topics of like import, as already stated in full in our report of 1899, pp. 11, 13. The recognition of the fact that the salt areas were in part, at least, of an earlier age than the surrounding Eocene Tertiary beds was recognized by Robertson as early as 1865. The structure of these peculiar Cretaceous areas was first interpreted in a very simple manner—they were thought to be apices of Cretaceous islands, once forming a ridge or "backbone" around which Eocene deposition took place (Hilgard, 1869). In our Report of 1899 we indicated where organic movements had evidently taken place in Tertiary times in some of these Cretaceous outcrops. (See p. 58.) In our Report of 1902 the greater part of the salt licks in Northern Louisiana were described in great detail by Veatch. Their quaquaversal or dome-like structure was then quite fully made out. The immense quantities of rock salt beneath these licks, however, was only surmised, and the real value of the "licks" scarcely appreciated.

A great boon to stratigraphic geology in our Gulf States has been the well records obtained subsequent to the discovery of oil in large quantities at Beaumont, Texas. "Salt licks," "islands," "buttes," "sour lakes," "quarries" or features that at once attract the attention in the usually monotonous sand and clay slopes of the Gulf Coast Tertiaries, by whatever appellation they may be characterized locally, seem to have this much in common—huge lenses of gypsum or limestone, or masses of rock salt, or both, located more or less centrally. The dip of the rocks about the periphery of such areas seems to be away from the central mass, often at a high angle. The longer we study these peculiar structures the more convinced are we that

1907. Bulletin No. 5. Plate II.



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although they may be located along lines of weakness, faults, or fractured anticlines, they are not to any great extent due to tangential, mountain-making forces, nor to volcanic upheavals, nor igneous plugs, as has recently been suggested, but to the slowly-acting, little understood, concretion-forming forces as well as the power of crystallization. Hot saline or calcareous solutions, coming from earlier Mesozoic or later Paleozoic beds beneath, rising perhaps by hydrostatic pressure alone, may very readily, upon reaching a level where the pressure is somewhat relieved and the temperature decreased, deposit some of their mineral contents.

Calcaceous concretions in shaly deposits in Paleozoic, Mesozoic or Cenozoic strata, seem to increase in size, bending adjacent shaly beds upward or downward with irresistible force, till the calcareous material within their reach, so to speak, is exhausted. If the supply were continuous, or not limited to the calcareous matter within a few yards radius, we see no reason why the concretion should not grow indefinitely. Though in some places there are Cretaceous limestones and sandstones, too, that have evidently been deposited in the regular way and contain well preserved upper Cretaceous marine fossils, no one, we think, can look upon the highly crystalline, cavernous, unfossiliferous Winnfield "marble" without a feeling that a great part of it has originated by some secondary process. Calcium carbonate has either leached into earlier calcareous beds laid down in the ordinary way, and has changed and inflated them beyond recognition, or has come into its place wholly by concretionary processes. In either case we believe the swelling up of this material, primarily Cretaceous, is largely responsible for the Winnfield quarry dome, and that vulcanism in its usually accepted sense has had nothing to do with the case. Igneous plugs and dikes usually cause great irregularities in the earth's magnetic field. How very slight are the irregularities in the Winnfield area may be seen by consulting Plate II. It would seem that perhaps a fault or a nearer approach of material of a different character from the ordinary Tertiary sands and clays is indicated by the trifling deflection of the south end of the needle towards a line indicated by heavy dashes on this Plate II. Deflections like these, detectable only by in-

struments specially constructed for terrestrial magnetic work, are scarcely of the kind that would be found if igneous activities had been at work in the region. The form of a dome depends, doubtless, largely on the position of most rapid increase in size of the formative masses, and this doubtless depends on lines of weakness in the superjacent strata. Some small areas may be so lifted that faults occur and the "lake" at the "marble" quarry and the expanse of water at Coochie brake, alongside of prominent upheavals, are doubtless to be looked upon as the downthrow side of faults of this kind. Sub-domes may be expected in a domed area. The apices of these minor domes, by their proximity to the surface and salt centers cause the minor barren tracts that go to make up the districts known by some such special name as "Cedar Lick," "Drake's salt works," and so on.

Cedar Lick.—After the past six years of prospecting with the drill about the various "islands," "sour lakes," "salt licks," "buttes" and so forth, we believe no one will dispute the extremely local character of the masses of rock salt found so generally beneath the localities designated by any of the above-mentioned names. Hundreds of feet of pure rock salt are found in some drill-holes, while less than a mile away even salt water may not be found at much greater depths. In the particular area under discussion, drilling had not at the time of our last visit been done in a sufficiently trustworthy manner to prove the position of the rock salt masses. But that they do exist beneath Cedar Lick (at no great depth, in some places, in case the region were properly explored) cannot be doubted. Similar structures but a few miles to the northwest, at Drake's old salt works, prove this, even if the extensive brine springs in the vicinity left any chance for doubt on the subject, for as a German writer has said, "Brine springs are the finger-posts to rock salt deposits." Enough boring has been done, however, to prove that in some places at least, over the salt mass there are thick layers of calcareous rock, often cavernous and containing considerable quantities of gas. About the periphery of each small "lick" in the Cedar Lick district there are slight elevations, somewhat higher than those a little farther away from the center of each

lick, so, although there are no actual rock outcrops in the district, some points in its stratigraphy can be surmised.

Good well sections in Cedar Lick, as we have said, are wanting. Not that no borings have been made in the region, but because of carelessness on the part of those interested to properly keep a log of the well, or desire on the part of the drillers to not let the public know how deep the drill was actually going, or what it was passing through. This much, however, is well established. Drilling has gone to a depth of at least 700 feet. Besides brine, gas has been met with in considerable quantities, so much so that a comparatively shallow vein has furnished a steady flow for over two years. When lighted the flame would furnish heat for a small boiler. It has gone to waste, however. The specimen of rocks encountered appear very much like the calcareous strata in the oil wells farther south, though in some cases here they appear to be extremely hard, suggesting even the ocurrence of chert nodules. These hard rock layers are said to alternate with sands and clays. In no specimens obtained from these drill-holes have we ever seen the slightest trace of organic remains. We are under the impression that they form lenticular concretionary masses whose origin has been referred to on a previous page. In Fig. 1, page 12, we have constructed an ideal section to show graphically our interpretation of the structure across the region of salt licks usually spoken of collectively as "Cedar Lick." Notice the licks themselves are represented as level tracts of land. Plate III shows something of the levelness and barrenness of these salty tracts. Here and there about their periphery are slight mounds, shown somewhat exaggerated by "H" in Fig. 1. At Goldonna, a few miles off our map to the northwest, in the old Drake Lick already spoken of, a well penetrated 300 feet of loose material, perhaps Quartenary or Tertiary sands and clays, then passed through 600 feet of limestone or gypsum, and then 1,400 feet of rock salt, finally ending in gypsum. And we believe Cedar Lick would show something the same section if boring were sufficiently prosecuted, though the lenticular masses of secondary material seem to be more prevalent here and the solid calcareous layers less persistent. The humps "H," in our estimation, owe their origin to

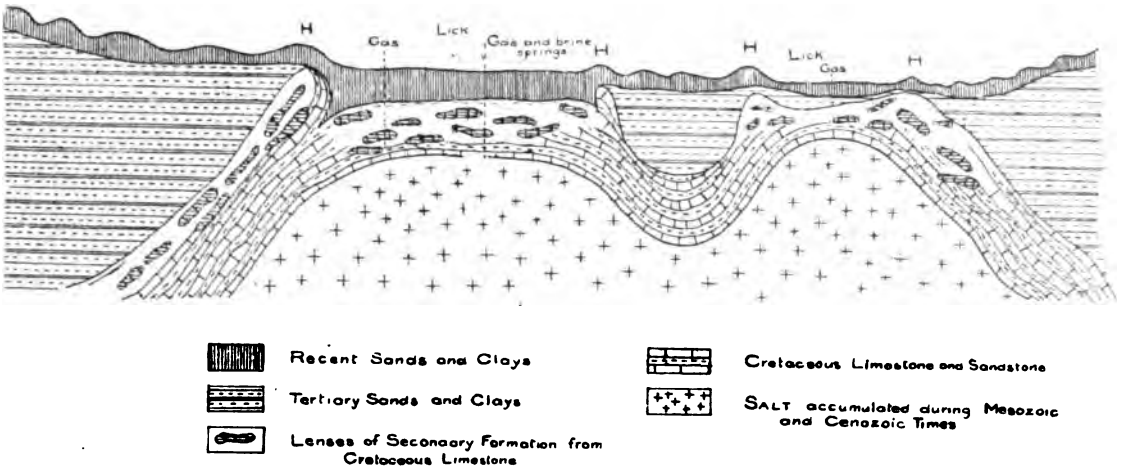


Fig. 1—Supposed structure of the rocks under Cedar Lick.
The Tertiary sands and clays should doubtless bend upward on approaching the Cretaceous uplift.

VIEW OF A PORTION OF CEDAR LICK, NEAR WINNFIELD LA. —Harris Photo.

either the presence not far below the surface of the upturned edges of indurated Cretaceous strata or calcareous material formed in a secondary manner from the Cretaceous material below, or perhaps to the outflowing of brines, or gases carrying and piling up arenaceous material in the form indicated. At Anse-la-Butte, in Southern Louisiana, the gravel and sand penetrated in the "hump" was said to be mixed with salt seams and lenses. At Rayburn's Lick fossiliferous Cretaceous strata are seen about the edges of the lick, as already described by Veatch. The gas that is generated in the lateral slopes of these domes works its way toward some fracture, pushing waters before it that have been rendered salty by being in proximity to the salt masses, and finally produces at the surface gas-brine springs—briny waters through which gas continuously bubbles.

Winnfield "Marble" Quarry.—We have discussed this locality in some detail in our Report of '99, pp. 56-58, and given some of the theories already advanced to account for this strange outcrop. These need not here be repeated, for the report referred to is accessible to all who write to the Director of the Experiment Stations for a copy. For convenience sake, however, we have inserted here the little detailed sketch map of a square mile around the quarry, made by Veatch and the writer eight years ago. The position of many little topographic characteristics are there shown much more clearly than on the small scale map, Pl. I. The photograph of Chimney rock we also repeat, Pl. IV.

Though the vertical part of the limestone outcrop at the Chimney may not be over 30 feet, one can, by properly searching in depressions and then following the beds upwards and beyond the top of the Chimney, find between 50 and 60 feet of strata exposed. It would seem from the locality shown in the photograph that the bedding planes (if such they really are) are nearly horizontal; by following the ridge a little to the northeast it becomes apparent that there is a very marked dip to the northwest. This seems to hold good to the Claiborne limestone outcrop, to the north on the bayou. In the bluff east of the bayou the dip swings around to the east. The small outcrops to the southwest are very unsatisfactory so far as showing direction and amount of dip. But the general impression obtained

from oft-repeated visits to all the various outcrops is: that upon the whole their dips and positions indicate that the uplift here recorded is elliptical dome-shaped, with the major axis running northeast-southwest; that this dome is fractured along its major axis, and that upon the whole the southern side of the fracture suffered depression while the northern remains well up with a monoclinal slope to the west of north. Something as to the dome-like structure of this vicinity can be gathered from the known outcrops of fossiliferous Claiborne beds as shown on the large map, Pl. I. The lake-like body of water to the southwest, as well as the swampy depression to the northeast of Jerusalem Church may have been caused in part by the orogenic movements more clearly recorded in the "quarry."

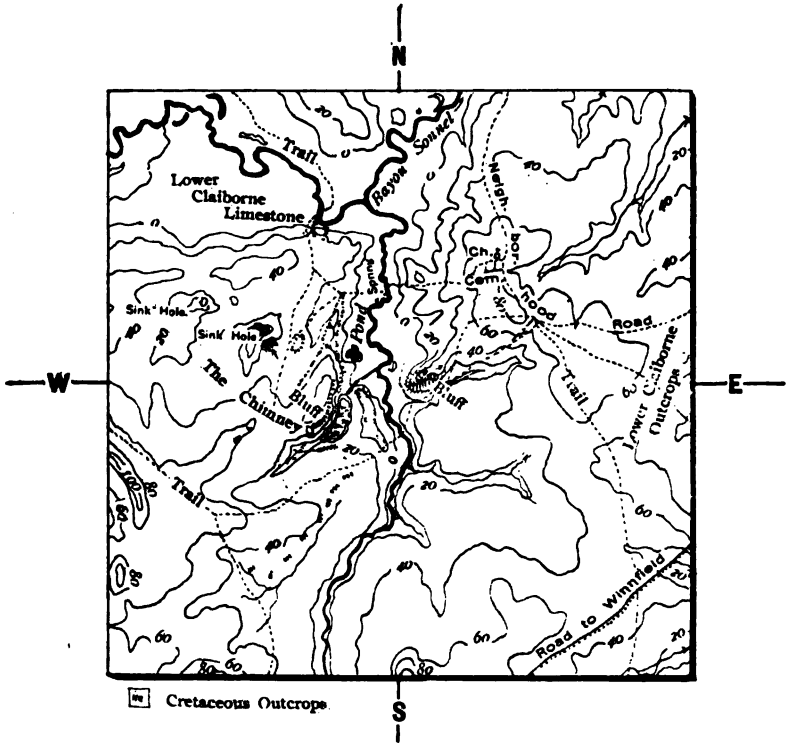


FIG. 3.—*Sketch of Winnfield "Marble" quarry and surroundings. This map embraces one square mile. Elevations are denoted by contour intervals of 20 feet, commencing with 0 at the base of the eastern bluff.*

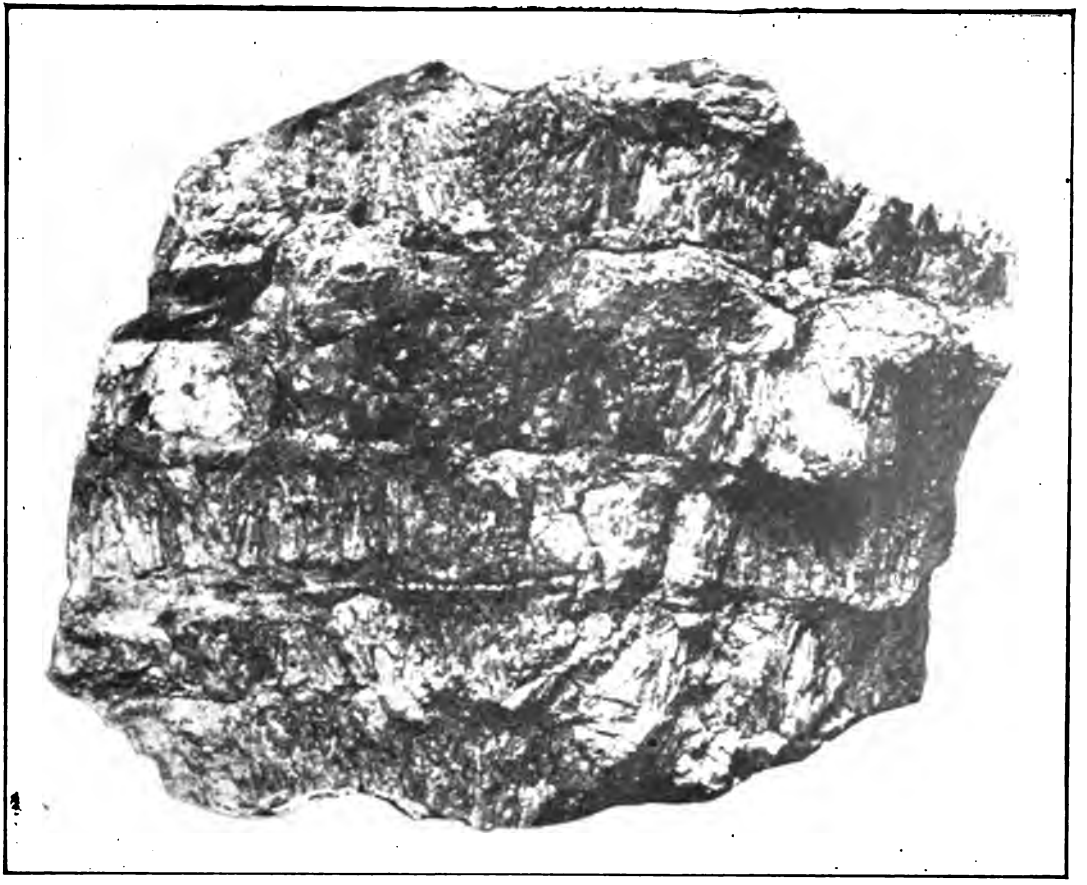
CHIMNEY ROCK, WINNFIELD "MARBLE" QUARRY, NEAR WINNFIELD, LA. —Harris Photo.

Throughout the 50 or 60 feet of limestone beds here exposed we have endeavored to see some change in rock character, but with practically no success. In some places, however, it seems as though the white and blue alternating laminæ differ in such a way in thickness that the blue are relatively more noticeable the lower one goes down in the section. The thick seams made of dog-tooth spar (Pl. V) have certainly been seen most abundantly near the top of the section, east of the bayou.

Perhaps one of the most interesting points relative to this vicinity is the occurrence in peculiar pockets in the bluff east of the bayou of a red, granular, porous limestone. The calcareous crystals are nearly transparent and glitter like fragments of glass. Among this reddish granular mass are remains of insectivorous mammalia and mollusks apparently of a land fauna.

The bold escarpment here referred to has nothing to suggest the former presence of a cave in this vicinity. But, there can be little doubt but that in Tertiary or Quaternary times the limestone beds were more extensive and contained caves in which this reddish limestone was deposited in the form of calcareous sinter, or partly, perhaps, after the manner of stalagmites. The very remarkable feature about this cave limestone is that in many places it is replete with minute long, hollow bones, evidently the finger bones of some species of bat. Occasional lower jaw bones are also found; sometimes tiny bones of other parts of the skeleton.

The comparatively recent age of this limestone is attested by the fact that it was formed in cavities in the common white and blue limestone of this locality, which latter as shown by the fact later on, has been more or less modified since Claiborne Eocene times; the great age, in years, is attested by the fact that although this limestone was formed in a cave, all traces of cave structures have disappeared.



A SPECIMEN OF WINNFIELD LIMESTONE, BANDED BLUE AND WHITE, SHOWING DOG-TOOTH SPAR.
(*Two-thirds natural size.*)

Coochie Brake.—This interesting locality is in the very southwestern corner of the map, Pl. I. Something as to the nature of the "brake" and the amount of valuable timber it contains have been given in our Report of '99. In that report too the outcrop of heavy sandstone beds was noted. Unfortunately we were told that the rock just referred to was somewhat differently located as to the land lines than we have more recently, by our own surveys found to be the case, but the remarks as to extent of outcrop, dip, and so forth made then are quite correct. Herewith we give (Pl. VI.) a somewhat different view of the rock outcrop, looking northwest instead of northeast, as in the plate shown in Report '99. The geologic structure of this locality is doubtless as already intimated, due largely to the swelling of gypsum or salt beds underneath causing here a fault or fracture in a northeast-southwest direction. The "brake" would seem to occupy the downthrow side of the fault, the rocky outcrop, the northern. Were it not for the underbrush and talus, the edges of the very heavy, apparently level beds could be well seen on Pl. VI. In mounting the escarpment shown, and looking toward the northwest it is at once obvious that the whole formation plunges beneath Tertiary sands and clays in the lowlands only a few hundred yards away. Although the rocky layers come to the surface for a distance of less than one-eighth of a mile, their presence is manifest by the soil-covered ridge extending nearly half a mile in a northeast-southwest direction, as may be seen by consulting the map. Again, although not over 40 feet of rocky ledges are to be seen in any one vertical escarpment, there is little doubt that the same material extends some distance below the top of the talus slope.

No animal remains have been found in the Coochie Brake beds. Fragments of wood and leaves are in places common. The most characteristic feature of the outcrop is the red iron stains due to the presence of large numbers of iron pyrites nodules.

—Harris Photo.

CALCAREOUS SANDSTONE OUTCROP AT COOCHIE BRAKE, ABOUT FIVE MILES WEST OF ATLANTA, LA.

CENOZOIC GROUP.

TERTIARY SYSTEM.

EOCENE SERIES.

SABINE STAGE.

Distribution and characteristics.—Just beneath the fine outcrop of fossiliferous Claiborne limestone to the north of Chimney rock at the Winnfield quarry there appear at least 30 feet of lignitic clay, dipping at an angle of from 10° to 40° in a westerly direction. Since the Claiborne limestone contains a very similar fauna to that of the calcareous marl at Natchitoches, and since there, too, dark, lignitic clays occur beneath the fossiliferous beds, and these we have referred to the Sabine stage, there seems to be no reason why the clays at the Winnfield quarry should not be referred to the Sabine, though as yet they have yielded no characteristic fossils. There are a number of species of fossil plants here, but thus far they have not been studied.

By consulting Pl. I it will be observed that the fossiliferous Claiborne surrounds the quarry in a more or less circular manner. Between the limestone outcrops and the Claiborne beds the strata are generally hidden by surface soils, but occasionally as in the banks of Rocky Bayou, south of the quarry, south of the highway, perhaps 150 paces south of "B. M. 152," some fine lignitic clay beds can be seen dipping east or in the opposite direction from the dips of the Sabine clays north of the quarry.

CLAIBORNE STAGE.

Distribution and characteristics.—Nearly all the area represented on our map is referable to the Claiborne stage. The Cretaceous and Sabine outcrops are very insignificant. In the southeastern part of the area certain gypsum-bearing clays and sands should probably be referred to the Jackson stage. East and northeast of Packton the water from shallow wells is impotable, and we have no doubt but that if there were a large number of excavations made in this district somewhere fossils would be found and they would most probably be of the upper Eocene or Jackson horizon. (See discussion below.)

West of the Mississippi River the Claiborne stage is usually

divisible in two parts, the lower, as a rule, quite fossiliferous, and the upper, often called the Cockfield sub-stage, quite barren so far as zoogene fossils are concerned, though abounding in fossil plants and lignitic clays.

The lower fossiliferous substage of the Claiborne is fairly well shown in the northwestern portion of the map, especially about the so-called "Marble" quarry. West of our map, in the vicinity of Couley, and north of the map, from Tannehill northward, this lower fossiliferous member of the Claiborne can be seen and studied. The greater part of the area mapped, however, must be referred to the upper, lignitic division of the Claiborne stage.

The Sabine beds exposed beneath the Claiborne limestone to the north of the "Marble" quarry have already been referred to. The lignitic clays give place above to calcerous clays of a light color, with here and there a mass of ferruginous sandstone. On the bottoms of these sandstones are found besides oyster shells, *Byssoarca, Capulus, Venericardia, Corbula, Lucina* and other marine bivalves. Still higher comes the great cream-colored limestone with its numerous oysters, *Byssoarca, Pseudoliva,* and a Nummulitic form in great quantities. This limestone is 8 or 10 feet in total thickness and dips westward at an angle of nearly 45°.

Practically all the lower Claiborne outcrops besides the one just described consist of calcareous, or red, ferruginous sands or sandstone beds. Occasionally, however, as in the prairie region 3 or 4 miles southwest of Calvin, light calcareous clays come to the surface and oyster shells can be picked up, not as mere casts, but in a well preserved condition. On the Montgomery road just south of the "Marble" quarry the highly ferruginous red fossiliferous sandy layers are well shown.

The thickness of the lower fossiliferous member of the Claiborne is probably not great, possibly not over 100 feet. Still, estimates of thickness are very unsatisfactory here owing to the few exposures that can be seen and studied. From the Atlanta well as given below it appears that 100 feet can be safely referred to this lower division.

DEEP CUT ON THE "VALLEY" ROAD THREE MILES SOUTHWEST OF WINNFIELD, LA.—Harris Photo

The upper or Cockfield member of the Claiborne is finely exhibited along the various railways crossing the area shown on the map, as well as in the upper reaches of the more important bayous. Sand and clay of a light hue generally, though darkened occasionally by lignitic material, constitute practically all this sub-stage of the Claiborne. Hardened or consolidated material is rarely met with. Fig. 3 shows how the first 300 feet of the L. & A. railway well at Winnfield penetrated nothing but alternating beds of sand and clay. The few thin rocks and the alternating or intermingled sands and clays below probably belong to the lower portion of the Claiborne and to the Sabine. No fossils were reported from this well. No detailed record seems to have been kept of the character or color of the various beds penetrated. However, by going on the "Valley" railroad about 3 miles toward Atlanta from Winnfield an excellent exposure can be seen of the upper Claiborne beds. A good view of the south side of the cut is herewith given as Plate VII. The different beds shown are as follows, beginning above (see Fig. 4):

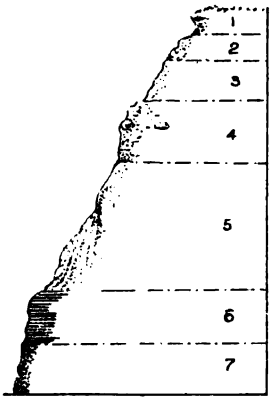


FIG. 4.—Diagram of the beds exposed in the cut shown in Plate VII.

	Feet.
1. Soil, red above	2
2. Sandy clay	2
3. Light sand	3
4. Sand, clay partings, with ferruginous concretions	5
5. Light sand, yellowish lines	10
6. Dark clay with leaves	4
7. Dark sand	4

As a rule, the sections along the "Valley" railroad show little variation in appearance and but few interesting structural features. At Atlanta, however, the Germain & Boyd Lumber Company put a well down 877 feet deep on the high hill just east of their mills, in section 26, perhaps three-quarters of a mile north-northeast of New Atlanta. The section furnished by this company reads as follows:

First 10 feet red clay mixed with sand.
From 10 feet to 30 feet white clay.
From 30 feet to 60 feet hard blue clay.
From 60 feet to 66 feet fine sand.
From 66 feet to 120 feet hard blue clay.
From 120 feet to 122 feet 8 inches hard rock.
From 122 feet 8 inches to 129 feet clay.
From 129 feet to 135 feet sand and clay.
From 135 feet to 229 feet blue clay.
From 229 feet to 241 feet sand.
From 241 feet to 270 feet hard clay.
From 270 feet to 287 feet coal or shale.
From 287 feet to 380 feet clay.
From 380 feet to 394 feet sand.
From 394 feet to 401 feet hard clay.
From 401 feet to 421 feet sand and soft clay.
From 421 feet to 475 feet hard clay.
From 475 feet to 503 feet hard clay with large boulders every few feet with small shells.
From 503 feet to 543 feet hard clay and boulders every few feet.
From 543 feet to 580 feet clay, shells and a little fine sand.
From 580 feet to 585 feet rock, clay and shells.
From 585 feet to 609 feet sand rock.

"We have no record below 609 feet; the total depth of the well is 877 feet; as I can remember it, it was sand rock below 609 feet most of the way until they struck the salt water 36 feet from the bottom; this was the first salt water struck. We went through a small stratum of sand from 380 to 394 feet containing fresh water."—GEORGE H. BOYD.

By searching in the sand that was said to have come from a depth of 500 feet we were able to obtain several small but typical lower Claiborne fossils.

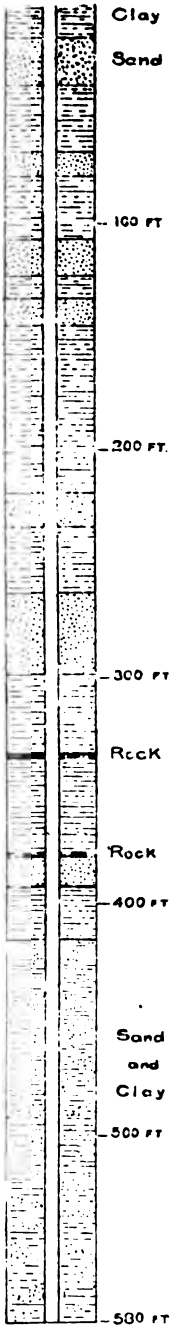


FIG 3—Well section at L. & A. railway station Winnfield, La.

The top of the fossiliferous beds here may be placed at approximately 200 feet below tide level. Nine miles to the north-northwest the uppermost fossiliferous beds seen were approximately 240 feet above tide. Hence the dip between the latter place and the Germain & Boyd well must be about 440 feet. Were it not for the Winnfield-Coochie fold that we have described as crossing this line of dip (see Plate II.) we believe the dip should be twice the amount just given, or even more, as will be apparent when the sections below are considered.

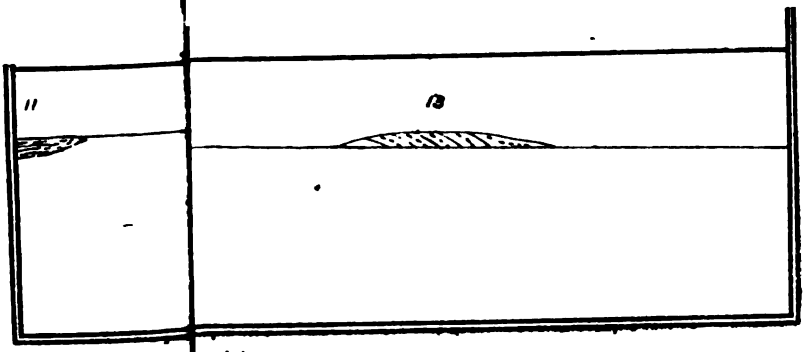
Section in Winnfield.—Just south of where the Georgetown road crosses the Arkansas Southern railway track, over a high bridge, about 20 feet of Tertiary strata are exposed. They appear to have a steep southern dip amounting to about 8 feet in 100; are of a light gray and yellowish hue, and show no very distinct and well-defined bedding. All may be called a clayey sand, with but comparatively unimportant differences.

Section along the L. & A. railroad, from Winnfield to Moore. - -Outcrop No. 1 (see Pl. VIII).—About one-quarter mile south of the trestle or the letter B in "B. M. 103" on the map, on the west side of the track one can see no less than 20 feet of very dark lignitic clay below the rails in the knolls excavated by the railway company for embankment purposes. Very little dip is here observed.

Outcrop No. 2.—About one-half mile north of "B. M. 133"—The depth and length of this cut can be ascertained by consulting Pl. VIII. At the north end cross-bedded sands occur; to the south beds of sandy clay form an arch or anticline.

No. 3.—One-third mile south of "B. M. 133."—This cut is characterized by its reddish sands. At the southern portion irregular bedding and flow-and-plunge structure are noticeable. The red sand beds often show white clay layers and pellets along their lines of parting.

No. 4.—Just south of "B. M. 107."—An old stream channel, ocupying the northern third is the most interesting feature of this cut. It shows occasional pockets of Pleistocene gravel The lower part of the cut, to the south, is occupied by typical lignitic sandy clays with thin yellow sand and ferruginous sandy partings.



, LA.

t. to the inch; vertical scale, 200 ft. to the inch.

No. 5.—Several small cuts occur along the railway to the south of Cedar Creek, but the most interesting is the one about half-way between "B. M.'s 131" and "163." Here may be seen two rows of "bomb-shells," about 3.5 feet apart vertically, and averaging perhaps 20 feet apart horizontally. These "bombs" are clay-ironstone concretions, of a deep red hue, sometimes a foot or more in diameter. The greater part of the exposure is made up of light sands with yellowish partings. Toward

FIG. 5—"Bomb-shells" on the L. & A. railway between Moore and Winnfield, La

the base more clay occurs and a tendency toward a chocolate hue appears. (See Fig. 5.)

No. 6.—On bank of stream just south of "B. M. 163."—Here is an extensive exposure of light grayish or olive sands with an apparent dip of one-sixth to the S. S. E. Cross-bedding is frequently seen. Great ferruginous concretions are imbedded in the light sand. Some concretions are of a very yellowish hue and seem decidedly calcareous.

No. 7.—Just north of "B. M. 186."—An uninteresting cut of sandy layers, dark above, lighter below, dipping slightly to the north.

No. 8.—Just to the south of "B. M. 186."—Three rather distinct layers are observable in this cut. Above are 8 feet of sand, becoming dark, to the south. In the middle are whitish clayey sands with blackish partings, 8 feet. At base are 10 feet of light clayey sands, slightly brownish in places, with yellowish partings.

No. 9.—One-half mile south of "B. M. 186."—A shallow cut of about 10 feet showing below reworked material, about 5 feet of cross-beddded scaly clays, with a slight dip to the south.

No. 10.—One-half mile north of Moore.—A cut 20 feet dep consisting of whitish and yellowish sandy layers separated by ferruginous scaly seams, slightly cross-bedded at north end of cut. Dip southerly about 1÷100.

No. 11.—In the west railroad ditch, about one-quarter mile north of Moore.—Light olive sands, about 20 feet exposed. Dip southerly, perhaps 1÷15.

No. 12.—At Moore, South from the road crossing. —An excellent exposure, showing interesting structural featurees. See Fig. 6: a, 7 feet of orange flecked white sand; b, light reddish sand; c, light sand 7 feet; d, concretions; e, 8 feet light sand

FIG 6—Details of cut at Moore, La.

with vertical ferruginous partings; f, lignitic sand, 3 feet; g, sands, sometimes purplish from decayed "bomb-shells", 5 feet; throw of faults, from 2 to 8 feet; direction of fault, E. 15° N.; hade, 20° to 40°. Downthrow on north side.

No. 13.—One-half mile to the south of No. 12 there is a low cut about 800 feet long showing at base light sandy clays, dipping 1÷15 southward; above are light reddish clayey sands, light yellowish when weathered.

There are no more cuts of importance to the south on this railway before the southern limits of our map are reached.

Cuts on the Arkansas Southern railway, south of Winnfield.—By consulting Plate VIII it will be seen that the exposures shown furnish but samples, as it were, of the strata that underlie this general region. It has not been possible to state which beds seen along the L. & A. are to be correlated with which on the Arkansas Southern. In fact, doubtless the majority of the beds seen on the one are not exposed on the other. Still, after arranging the manuscript notes of a section along the latter road in the same way we have arranged those along the L. & A., it becomes apparent that they agree in materials exposed, in cross-bedding, faults, jointing, etc., that is there are no materials in the one not shown in the other, but the identification of the same bed or the same structural feature on both roads cannot well be made, though the roads are very near together. The materials of which the upper Claiborne beds are made are subject to marked variations in very slight distances.

Thickness of the upper Claiborne deposits.—From dip calculations along both the L. & A. and the Arkansas Southern we have found that the thickness of the upper unfossiliferous portion of the Claiborne must be at least 1,000 feet to the south of Winnfield. But if we add 400 feet more as the well section at the L. & A. station would seem to call for, we have a total of 1,400 feet as a minimum. This seems excessive, but when we realize that the fossiliferous lower portion of the Claiborne is perhaps not over 100 feet thick, the total for the Claiborne is 1,500 feet, still somewhat in excess of previous estimates for this stage in Louisiana, but one that present indications would show to be a minimum rather than a maximum figure.

JACKSON STAGE.

The presence of this stage in the area represented by the map has not been proven by fossil remains. We have indicated the probable occurrence of Jackson beds in the southeastern corner of this area because just over the parish line south of Prairie Home P. O. well preserved Jackson fossils occur. The strike of the beds here is a little north of east, so that the boundary line between Jackson and Claiborne stages might well be expected to pass across the southeast corner of our map. The general occurrence of extremely "bad" water with marly clays containing quantities of selenite crystals in the vicinity of Pleasant Hill Church and between here and the parish line to the south suggest materials and conditions of depositions much more in harmony with the Jackson than the upper part of the Claiborne stage.

QUATERNARY SYSTEM.

Little is known of the condition of affairs in central Louisiana during the Tertiary after the Jackson stage. The Oligocene, Miocene, and, perhaps, Pliocene are not recorded by any recognizable materials of deposition. This area was most probably much higher during the middle and upper Tertiaries than it is to-day. Doubtless, as we have already remarked, some of the main topographic features were outlined before the end of the Tertiary. Yet, much of the region herewith mapped is characterized by sharp and youthful topographic features, and erosion is going on apace in the upper reaches of the main streams. Hence, doubtless, all of the minor topographic features were wrought during comparatively recent or Quaternary times. We strongly suspect that during the later Tertiary the whole Dugdemona valley was carved much deeper than it appears to be to-day and that a great amount of re-filling has taken place in Quaternary times. On the hill land there is a remarkably small amount of material that can be looked upon as having been transported far or as being re-worked to any extent from the Tertiaries below. In the cuts on the "Valley" railway but a short distance south of the station, five or six feet of unstratified material can be seen on top of the stratified Tertiary. Here, too, generally at the base of the former are numerous fragments of petri-

SILICIFIED WOOD IN ROAD SOUTH OF WINNFIELD, LA.

fied wood. Sometimes they may be seen as chunks or logs, but as a rule they are mere splinters, nearly always with sharp edges, showing little or no erosion. Fossilized wood occurs as logs of considerable size on the surface of the ground on the hills beyond the salt licks southeast of Winnfield. On the first hill south of the L. & A. station in Winnfield many of these petrified logs may be seen along the highway. (See Plate IX.)

Pebble beds, so extensively displayed in many regions on the Gulf slope, just at the base of the so-called "Orange Sand" of the old school of geologists, are comparatively unimportant in this region. We have already noted a few pockets with pebbles along the L. & A. railroad section; and others can be seen six or eight miles south of Winnfield on the Arkansas Southern. They are surprisingly insignificant in comparison with deposits of similar material in, for example, Catahoula parish, or Rapides, in the hilly regions. These pebbles are composed of chert and often contain Lower Carboniferous fossils. They evidently have been extensively water-worn, and oxidized to the last degree. They came from Indian Territory, northwest Arkansas, Kansas or Missouri, for their contained fossils show this, but the method of transportation is still not well understood. Along an old trail perhaps two miles northeast of Packton we observed a very large chert pebble or rock, at least eight inches in diameter. It is certainly difficult to explain its presence here without invoking the agency of floating ice.

ECONOMIC PRODUCTS.

WATER.

In a region underlain by very irregularly lense-shaped masses of clay and fine sand, containing joints, faults, and many local folds, there is no hope of meeting with a well-defined, easily recognizable water-bearing horizon, like the Potsdam or Dakota sandstone in the North and West. Again, underneath these irregular sand and clay beds there are anticlines and faults in the Cretaceous rocks, and the Cretaceous is locally pregnant with rock salt. Brines therefore may leach up through several hundred feet of the above-described clays and sands. The difficulties to be met with in supplying a town, for example, with

deep well water are therefore great. In spite of these discouraging features, however, water may be obtained in most places in abundance by utilizing whatever water is found in each sand stratum penetrated. Since these strata are numerous the supply from one well can be made very considerable. The Clifford Well Company obtained a supply at the L. & A. station at Winnfield of 90,000 gallons daily within 580 feet, from a 3-inch well. To go deeper than this would be to run the chance of striking salt water, especially in this particular vicinity, where we believe a Cretaceous ridge occurs at perhaps a depth not much greater than 1,000 feet. The same conditions prevail at Atlanta where the Germain & Boyd Lumber Company reached very bad, salty water at 841 feet. Its analysis is as follows:

"From Germain & Boyd, Atlanta, La., Winn Parish, submitted by Judge P. J. Patorno, 506 St. Philip street, city.

(Analysis expressed as grains per U. S. Gallon.)

Sodium Chloride	353.672
Sodium Carbonate	7.128
Potassium Sulphate	1.792
Potassium Carbonate	0.470
Magnesium Bicarbonate	8.126
Calcium Bicarbonate	12.886
Iron and Aluminum Oxides	0.139
Silica	0.435
Volatile Matter	Trace.
Bromine	Trace.
	384.748
Calculated excess water	2.448
Total	382.300

"Remarks—This water is decidedly salty and contains twenty-one (21) grains of incrustating material to the gallon. This water is unfit for boiler, technical, or domestic purposes. Its only use would be for extinguishing fires. This water energetically and actively attacks galvanized iron. DR. A. L. METZ."

To the south of Winnfield there should be no great difficulty in obtaining a good supply of water by utilizing whatever

each sand bed carries. In the very southeastern part of the area covered by the map doubtless the water obtained from the selenite bearing clays and sands to a depth of 50 to 100 feet would have to be cased off from the supply found in the good water-bearing sands lower down.

In the western part of the area mapped, west of the "Marble quarry," for example, in the long-leaf pine woods, the extensive superficial deposits of fine sand absorb immense quantities of rain water, and, whenever this reaches an impervious clay layer that lies above the valley bottoms, it comes out in springs of large size and most excellent quality for drinking purposes. A few of these springs we have noted on the map. Deep well water in this region should be obtained if desired, as in the area to the south of Winnfield. The region about Calvin presents somewhat greater difficulties as to deep well water, for the Claiborne beds near or at the surface would be more than apt to carry bad-tasting mineral waters. The Sabine stage is that which if properly worked would yield fair water at less than 600 or 800 feet. Depths greater than that would furnish, locally, at least, salt waters. To the northeast of Winnfield across the Dugdemona, there are so far as we are aware no deep wells, but there appears to be no reason why they may not be obtained as satisfactorily as at Ruston, for the formations encountered are alike in the two localities.

SALT.

The extensive salt licks a few miles southeast of Winnfield, as already described, leave practically no doubt as to the presence there of immense beds of rock salt within a few hundred feet of the surface of the ground. In exploiting this region for mining it is worth while to make sure of two things—first, that the location for a shaft is at the place where the salt approaches near the surface and, second, that the salt is capped with a considerable thickness of solid rock.

At Ithaca, N. Y., fresh water is turned into drilled wells sometimes 2,000 feet deep or more. After saturation from being in contact with the rock salt mass the water is forced up and evaporated by the exhaust steam from the street car power plant.

This use of superfluous heat about the many large Winnfield mills should certainly be considered by their owners. Again, in the Winnfield salt lick district the salt or brine springs, as well as the "oil" well already bored, prove the existence of no inconsiderable amount of gas in the region. The burning of such gas as can easily be obtained should also furnish a sufficient amount of heat for evaporating large quantities of table salt.

GAS.

A considerable amount of gas is escaping from the various brine springs in Cedar lick, and the "Blow-out" well has produced brine and gas for nearly two years. But, upon the whole, we are not inclined to think that immense quantities of gas are pent up in these salt domes. Such gases as have been generated in the district have had too easy ways of escape to have accumulated in large quantities, producing great gas pressure over large areas. Yet nothing short of actual testing with the drill will show how much gas may be obtained.

LIMESTONE.

We have had occasion frequently to refer to the so-called Winnfield "Marble quarry." The value of the material there shown as "marble" is but slight. As limestone for burning to quicklime and as an important ingredient for cement and soda ash manufacture its value is great. By comparatively little stripping, limestone rocks could be exposed for a distance of half a mile in a northeast-southwest direction and from an eighth to one-fourth mile in a northwest-southeast direction.

For the manufacture of cement, clays just beneath the Claiborne limestone to the north of the 'quarry." as already described, should be studied carefully. Other clays can be found exposed in railway cuts; for example, near the brickyard in West Winnfield or in the great cut shown as Plate VII. For the manufacture of soda, a test well should be first put down near the "quarry" in search of salt. It is quite possible that rock salt may be found beneath the limestone. However, by the construction of short tram lines or spurs from the "Valley" or the L. & A. railroad, limestone may easily be brought to Winn-

field and brine may be pumped there from the lick to the southeast. By consulting the map, Plate I, it is easy to see that with but one cut of importance a railroad could be laid out from, say, "B. M. 184" on the Montgomery highway east joining the "Valley" railroad at "B. M. 153." Connections from the quarry down the bayou to "B. M. 112" or "113" on the L. & A. could be readily made.

BUILDING STONE.

The bluff of calcareous sandstone (often heretofore improperly called limestone) is of excellent quality for construction purposes, but, owing to the pyrite concretions it contains, it could not well be used for facing or ornamental stone work. Some have supposed the quantity of this sandstone to be limited to what is in sight now at the "brake." The topography to the northeast, however, indicates clearly that by stripping, a quarry one-half mile could be opened up.

MAR 31 1909

BULLETIN No. 6 REPORT of 1907

GEOLOGICAL SURVEY OF LOUISIANA

G. D. HARRIS, Geologist-in-Charge

CARTOGRAPHY

OF

SOUTHWESTERN LOUISIANA

WITH SPECIAL REFERENCE TO THE

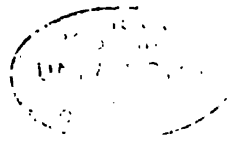
JENNINGS SHEET

BY

G. D. HARRIS

Made Under the Direction of the State Experiment Stations
W. R. DODSON, Director

BATON ROUGE
1907



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H. R. FULTON, M.S., Plant Pathologist, Baton Rouge.
J. T. TANNER, Secretary and Stenographer, Baton Rouge.
E. J. WATSON, Horticulturist, Calhoun.
IVY WATSON, Farm Manager, Calhoun.
C. M. GRISHAM, Dairyman and Poultryman Calhoun.
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THE BULLETINS AND REPORTS will be sent free of charge to all farmers, on application to the Director of the Stations, Baton Rouge, La.

CARTOGRAPHY OF SOUTHWESTERN LOUISIANA

WITH SPECIAL REFERENCE TO THE

JENNINGS SHEET

By G. D. HARRIS

INTRODUCTION.

The area shown on the map which accompanies this Bulletin is but one of many in Southern Louisiana that deserve immediate attention from State and National surveys. The old Land Office maps, though showing accurately enough the metes and bounds of land grants and claims, give almost no idea of the surface features of the land, practically no roads, railroads, villages, towns nor houses as we find them today. As a matter of convenience to the people dwelling in these areas, for planning their roads, railroads and especially their canals and levees good topographic maps cannot be too quickly constructed. The great value of reliable determinations of the elevations of a great number of road-crossings, bridges and other points all over the area, and the value of the permanent iron bench-marks left every few miles along the railway track, must be apparent to all who are interested in canal work and rice culture. Again, the prospective immigrant must be greatly influenced by an authoritative map indicating just what he may expect to find in any particular region.

FORMER SURVEY WORK IN SOUTHWEST LOUISIANA.

Reference has already been made to the Land Office maps, made for the most part years ago, showing practically none of the roads, towns, etc., as we see them today, but showing generally the larger streams, sometimes with great detail, but indicating the lesser streams in a most crude manner. Several of the parishes have published local maps, usually the area within their own confines, basing the whole mainly on the old Land Office maps, but indicating the towns and the general direction of the roads as they were understood at the date of publication. The so-called

State maps published by geographic publishing companies as well as the maps of Louisiana found in atlases, are mainly from this same source and are of about the same order of merit as the parish maps just described.

In Bulletin No. 1 we have attempted to give an approximately correct idea of the topography of Southwestern Louisiana by means of contour lines. The data for the same were derived from railway, canal and lines of private sources.

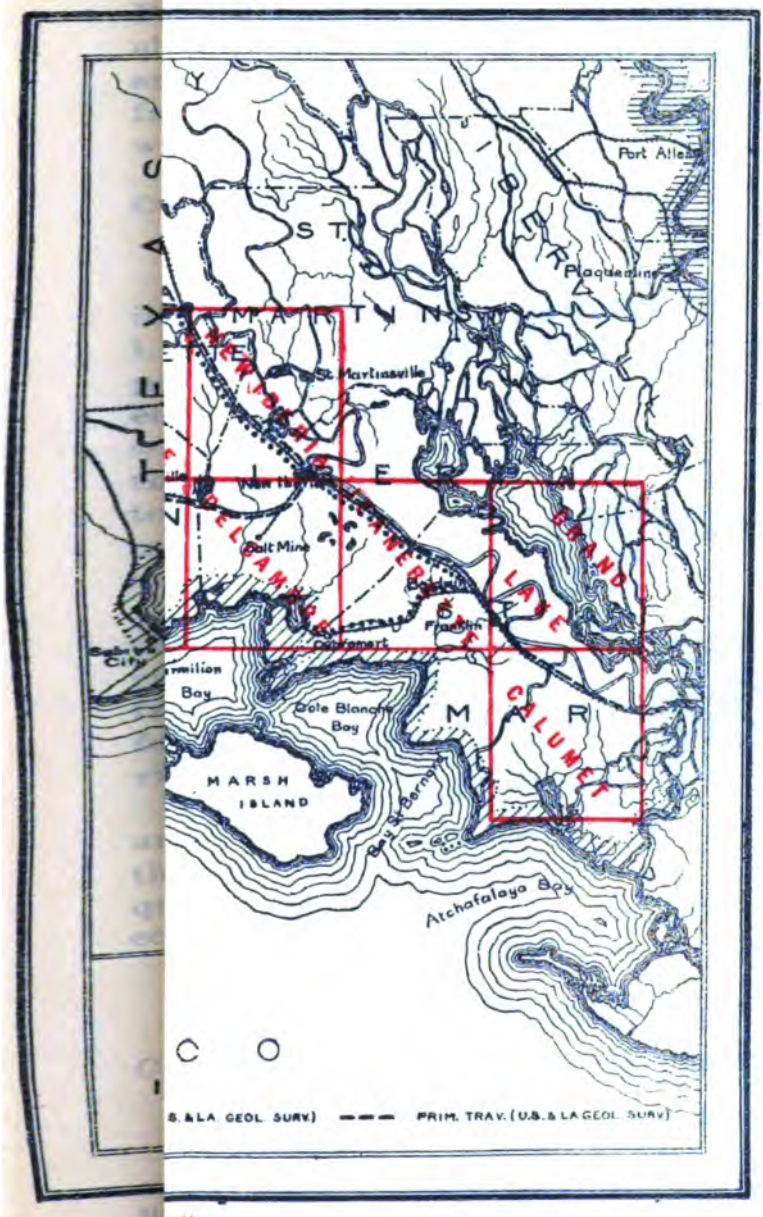
In all such maps, however, the determinations of elevation as well as latitude and longitude must be considered as but approximately correct.

Cartographic work of a high order was begun in Southwestern Louisiana by the members of the Coast and Geodetic Survey in about 1866 and since that time such coastal areas as are indicated on the accompanying outline map (Pl. X) have been carefully mapped.

Up the Mississippi River and even the Red, triangulation and precise level work have been carried. But the great stretch of country to the south of Alexandria, until the coast is reached, is practically uncontrolled, either laterally or hypsometrically.

RECENT CO-OPERATIVE SURVEY WORK.

In starting cartographic work in this section of the State it was necessary to consider the most expedient methods of primary control. So far as hypsometry is concerned, the Survey had the foresight two years ago to establish, with the co-operation of the Coast and Geodetic Survey, a tide station where the height of the surafce of the gulf is continuously recorded. All this work is fully set forth in Bulletiu No. 3 of our report of 1905. On page 14 we read: "Our intention is, by a long series of tide-gauge readings, to determine the elevation of a few seacoast bench-marks with great accuracy, and from them run a line of precise levels along the Southern Pacific railroad and establish at intervals of every five miles permanent bench-marks and thereon give the true height of the same above sea-level. All local lines can then be referred to one datum plane and when local surveys extend for a few miles in an east-west direction both ends can be tied to reliable bench-marks and the accuracy of the local survey


Port Allen
Plaquemine
St. Martinsville
Belle Mine
Vermilion Bay
Cote Blanche Bay
MARSH ISLAND
Atchafalaya Bay
PRIM. TRAV. (U.S. & LA GEOL. SURV.)

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can be tested without the expense of duplicating all the work. Fairly reliable local bench-marks many miles distant from the above-mentioned railroad will very soon be felt by local engineers and the mapping of the region topographically will be greatly facilitated. The time saved in running and re-running level lines will in a few years amount to tens of thousands of dollars."

CO-OPERATIVE WORK WITH THE U. S. GEOLOGICAL SURVEY.

The tide-gauge has already served one purpose for which it was established, the one indicated in the paragraph above—i. e., the furnishing mean sea-level for precise leveling in this part of the State. In the fall of 1906, the State Geological Survey co-operated with the United States Geological Survey and ran a series of levels from Weeks Island (tide gauge station) along the Southern Pacific spur to Baldwin, thence to Lafayette, thence to Jennings along the Southern Pacific Railroad, establishing and marking bench-marks along the right of way about every four miles. (See the accompanying outline map, Pl. X.)

So far as horizontal control is concerned, co-operating with the U. S. Geological Survey, the State Survey has been able to run a line of primary traverse from Morgan City, on the Atchafalaya, along the line of the Southern Pacific Railroad to Lafayette, thence to Jennings, back via Midland, Gueydan, Abbeville, New Iberia and Morgan City again. (See Pl. X.)

The results of the co-operative work with the United States are such that a large number of the 15° quadrangular maps in this part of the State are controlled in a primary manner. (See quadrangles in red, Pl. X.) These we propose to take up and complete as rapidly as funds will permit.

CO-OPERATIVE WORK IN PRECISE LEVELING.

(Notes furnished by the Computing Division, U. S. Geol. Survey.)

Crowley, Delcambre, Jeanerette, Jennings, Lafayette and New Iberia Quadrangles.

Acadia, Calcasieu, Iberia, Lafayette and St. Mary Parishes.

The following are the unadjusted results of a precise level line run in the fall of 1906, beginning at Weeks Island and fol-

lowing the line of the Cypremort Branch of the Southern Pacific Railroad to Baldwin, thence westward along the main line of the Southern Pacific Railroad to Jennings, a total disant of about one hundred miles. The work was done in co-operation with the Louisiana Geological Survey, Prof. G. D. Harris, Geogolist-in-charge, who established an automatic tide-gauge on Weeks Island in February, 1905. Records have been kept continuously since and will be continued for some years under the direction and at the expense of the United States Coast and Geodetic Survey. The line was started from a bench-mark established by Prof. G. D. Harris, and known as bench-mark No. 2, also upper bench-mark No. 1, and is the rounded top of a brass plug protruding through cap on iron post which is set about 250 yards west of the terminus of the railroad at the Weeks Island Salt Mine, and about 0.75 mile easterly from the tide-guage. The elevation as determined by the Coast Survey is 19.36 feet above the mean sea level.

Thirty-seven standard bench-marks were set at intervals of not more than 4 miles apart. The total divergence between direct and reverse lines was 0.061 foot.

The methods of leveling, type of level and limit of error are those now used by the Coast and Geodetic Survey except that the rods were graduated to yards and hundredths instead of in meters. They were non-extensible self-reading and 3.5 yards in length. The readings were taken to thousandths by estimating the smallest graduation, the sum of three readings giving the mean reading in feet.

The line was leveled independently in both forward and backward directions, broken by temporary bench-marks into sections 0.5 to 1.25 mile long and on all sections upon which the forward and backward measures differed more than $0.017 \sqrt{D}$ (in which D is the distance between bench-marks in miles), forward and backward measures were repeated until a pair run in opposite directions checked within limits.

The party consisted of five men—two rodmen, an umbrella-man and one recorder under Mr. E. L. McNair, topographer, under the supervision of Mr. S. S. Gannett, geographer.

Standard bench-marks are stamped with the letters "LA" in addition to figures of elevation, mostly to nearest foot.

DELCAMBRE QUADRANGLE.

Weeks Island via Cyrpemort Branch Southern Pacific Railroad to Baldwin.

Weeks, shafthouse at Salt Mine, 150 yards west of; road to tide house, 20 feet to right of; iron post (Established by Prof. G. D. Harris of La. Geol. Survey) 19.360
Cypremort, 0.69 mile west of; road crossing; top of rail 3.2
Cypremort, in front of station; top of rail 7.8
Cypremort, 600 feet east of station of S. P. R. R., 22 feet north of main track, at cattle guard, iron post stamped "8" 7.662
Alice B station, at road crossing, top of rail 8.6
Alice B station; 0:35 mile east of; road crossing, top of rail 8.7
Ivanhoe station, at road crossing, top of rail 7.5
Florence station, top of rail 7.6

JEANERETTE QUADRANGLE.

Cote Blanche station, in front of; top of rail 7.7
Cote Blanche station, 100 feet east of highway crossing, 20 feet north of center of track, iron post stamped "7" 7.195
Richland, top of rail 9.7
Glencoe, top of rail at station 11.3
Glencoe, southeast corner of station, 5 feet north of platform steps, 30 feet north of main track, iron post stamped "10" 9.531
Glencoe, 0.9 mile east of station, road crossing; top of rail 6.8
Glencoe, 1.60 miles east of; spur track to sugar mill, top of rail at switch stand 7.4
Glencoe station, 2.16 miles east of; road crossing, top of rail 5.7
Vacherie, 0.2 mile west of station, 240 feet west of highway crossing, 45 feet south of railroad and 15 feet southwest of corner of section tool house, iron post stamped "6 LA" 6.071
Vacherie, road crossing, top of rail 6.2
Vacherie, 0.3 mile east of; road crossing, top of rail 6.2
Franklin and Abbeville Junction, 20 feet west of end of station and 18 feet north of track (Weeks Island Branch), iron post stamped "5 LA" 5.043

Franklin and Abbeville Junction, top of rail..... 5.7
Franklin and Abbeville Junction, 1.20 miles east of; road crossing, top of rail.....11.4
Baldwin, in front of station; top of rail.....12.9
Baldwin, 100 feet northwest of station; 25 feet west of center of highway, 15 feet southof switch, iron post stamped "11 LA".....11.030

Baldwin via Southern Pacific Railway to Lafayette.

Baldwin, 1.0 mile west of; south of track, telegraph pole, spike in base of..... 6.02
Adeline, 1.4 miles east of; road crossing, top of rail.....13.2
Adeline, 0.7 mile east of station; south of track and 150 feet west of mile-post 108, telegraph pole, spike in base of 10.16
Adeline, in front of station; top of rail.....14.6
Adeline, 210 feet west of; south of track, telegraph pole, spike in base of.....11.184
Adeline, 220 feet west of; about 30 feet north of track, iron post stamped "14 LA".....13.827
Adeline, 0.53 mile west of; south of track, telegraph pole, spike in base of.....12.60
Adeline, 0.80 mile west of; road crossing, top of rail.....16.8
Adeline, 1.40 miles west of station; road crossing, top of rail 18.3
Adeline, 1.46 miles west of; telegraph pole, south of track, spike in base of.....16.32
Adeline, 2.44 miles west of; telegraph pole, south of track, spike in base of.....12.77
Jeanerette, 2 miles east of; road crossing, top of rail.....17.7
Jeanerette, 1.91 miles east of; telegraph pole, spike in base of 14.93
Jeanerette, 1.20 miles east of; road crossing, top of rail.....19.7
Jeanerette, 0.82 mile east of; spike in base of telegraph pole, south of track, near eastern city limits.....18.34
Jeanerette, 0.9 mile east of; road crossing on parish line (Iberia and St. Mary parishes), top of rail.....19.8

Jeanerette, 0.8 mile east of; 30 feet east of highway, on St. Mary-Iberia parish line, 45 feet north of north track, iron post stamped "17 LA" 17.351
Road crossing, top of rail 19.4
Jeanerette, in front of station; south side of track, telegraph pole, spike in base of 17.71
Jeanerette, in front of station; top of rail 18.7
Jeanerette, 0.3 mile west of station; road crossing, top of rail 18.6
Jeanerette, 1.10 miles west of; road crossing, top of rail 19.3
Jeanerette, 1.25 miles west of; telegraph pole, spike in base of 17.08
Jeanerette, 1.1 miles west of; 57 feet south of railroad track, 45 feet west of center of highway, near fence, iron post stamped "17 LA" 16.785
Jeanerette, 2.30 miles west of; crossing of Narrow Gauge Plantation Railroad, top of rail 20.9
Jeanerette, 2.4 miles west of; spike in base of telegraph pole 16.96
Olivier, 3.2 miles east of; station; south of track, spike in base of telegraph pole 16.35
Olivier, 2.1 miles east of; south of track, spike in base of telegraph pole 17.15
Olivier, 1.1 miles east of; railroad drain; 8-penny nail in top of plank at south end of 18.04

DELCAMBRE QUADRANGLE,

Olivier, 0.2 mile east of station; crossing of Narrow Gauge Plantation Railroad, top of rail 21.8
Olivier, in front of; telegraph pole, spike in base of 20.06
Olivier, in front of station; top of rail 21.6
Olivier, 54 feet west of station; 25 feet north of north track, iron post stamped "Prim. Trav. Sta. No. 29," "21 feet LA" erroneously stamped 19.442
Olivier, 0.9 miles west of station; south of track, telegraph pole, spike in base of 18.37
Olivier, 1.70 miles west of; road crossing, top of rail 21.5
Olivier, 1.87 miles west of station; south of track, spike in base of telegraph pole 17.50

New Iberia, 2.75 miles east of; 225 feet west of highway crossing, 57 feet south of south track, iron post stamped "17 LA" 16.939
New Iberia, 1.5 miles east of; city limits, road crossing, top of rail 21.0
New Iberia, 1.5 miles east of; south of track, 450 feet east of mile-post 124, spike in base of telegraph pole 18.97
New Iberia, 1 mile east of; road crossing, top of rail 21.0

NEW IBERIA QUADRANGLE.

New Iberia, 1 mile east of; road crossing, top of rail 20.5
New Iberia, 0.5 mile east of; spike in base of telegraph pole north of railroad at junction Weeks and East Washington streets 18.35
New Iberia, U. S. Post Office Building, in face of foundation at right of main entrance, aluminum tablet stamped "23 LA" 23.236
New Iberia, water plug just east of station; top of bolt in northeast corner of base, painted white 21.12
New Iberia, in front of station; top of rail 20.0
New Iberia, water tank opposite station; 55 feet east of and 100 feet south of track; iron post stamped "27 LA?" 19.059
(Notes say this is stamped "27," but it is probably incorrect.)
New Iberia, 0.9 mile west of station; south of railroad, spike in base of telegraph pole 22.73
New Iberia, 1.70 miles east of; road crossing top of rail 23.4
Segura, 0.8 mile east of; south of track, at base of telegraph pole, nail in peg 21.10
Segura station, 0.10 mile east of; road crossing, top of rail 27.9
Segura, in front of station; top of rail 28.5
Segura, 0.13 mile west of; north of track, spike in base of telegraph pole 26.78
Segura, 600 feet west of station; in southwest corner of yard, 70 feet north of S. P. R. R., iron post stamped "28 LA" 28.362
Segura station, 0.26 mile west of; road crossing, top of rail 30.60
Segura, 1.2 miles west of station; south of track, spike in base of telegraph pole 26.89
Segura, 1.9 miles west of; road crossing, cattle guard No.

131 A-B, top of rail 31.90
Burke, 0.06 mile east of station; spike in base of telegraph pole 29.54
Burke, 28 feet north of track; 20 feet east of public highway, iron post stamped "27 LA" (erroneously stamped) 27.999
Burke, in front of station; top of rail 30.20
Burke, 0.89 mile west of; spike in base of telegraph pole 25.71
Burke, 1.59 miles west of; road crossing, top of rail 27.8
Cade, spike in base of telegraph pole 29.92
Cade station, in front of; top of rail 30.7
Duchamp station, 165 feet east of; north of track, spike in base of telegraph pole 33.47
Duchamp, 20 feet east of highway; 25 feet north of track, iron post stamped "Prim. Trav. Sta. No. 32," "33 LA" 33.167
Duchamp, in front of station; top of rail 35.7
Duchamp, 0.5 mile west of; road crossing at cattle guards 135 D-E 36.0
Duchamp, 1.33 miles west of; south of track, spike in base of telegraph pole 28.68
Duchamp, 1.5 miles west of; road crossing at St. Martin-Lafayette parish line 34.6
Billeaud Sugar Mill, 0.71 mile east of; spike in base of "block signal line pole" 33.35
Billeaud Sugar Mill, top of rail at road crossing and station 34.1
Billeaud Sugar Mill, about 500 feet west of; spike in west tie under switch stand, 1.5 feet south of switch lock, near cattle guard, 138-A 34.71
Billeaud Sugar Mill, 500 feet west of; 30 feet north of track, iron post stamped "35" 35.325
Billeaud Sugar Mill, 0.90 mile west of; road crossing at cattle guard 138-D 35.6
Billeaud Sugar Mill, 1 mile west of; road crossing, top of rail 36.7
Broussard, station, telegraph pole, spike in base of 37.63
Broussard, 30 feet east of station; 25 feet south of track in corner of yard, iron post stamped "37 LA" 36.878

Broussard, in front of station; top of rail.....37.2
Broussard, 1 mile west of; south of track, spike in base of telegraph pole.....34.62
Broussard, 1.72 miles west of; 450 feet west of mile-post 140, spike in base of telegraph pole.....30.79
Landry station, top of rail.....34.0
Landry P. O., 0.61 mile west of; signal tower No. 1424; battery box, top of clasp on east end of east box.....36.99
Landry, 0.61 mile west of; road crossing.....37.2
Landry station, 0.61 mile west of; 18 feet north of track, public highway, 20 feet west of; iron post stamped "36 LA".....36.645

LAFAYETTE QUADRANGLE.

Lafayette, 2.23 miles east of; bridge No. 143 A, 450 feet west of; telegraph pole, spike in base of, south of track.....38.53
Lafayette, 1.73 miles west of; road crossing, at cattle guard 143 C-D.....30.7
Lafayette, 1.18 miles east of; 265 feet east of road crossing, spike in base of telegraph pole.....30.79
Lafayette, 1.18 miles east of; public highway, 20 feet east of; 30 feet south of track, iron post stamped "36 LA".35.797
Lafayette, 1.18 miles east of; road crossing, at Lafayette Sugar Mill.....35.4
Lafayette, 0.80 mile east of; road crossing.....38.3
Lafayette, 0.60 mile east of; road crossing.....37.4
Lafayette, in front of station; top of rail.....39.4
Lafayette freight house yard, southeast corner of, on Lincoln avenue, iron post stamped "Prim. Trav. Sta. No. 34," "39 LA".....39.114

Lafayette via Southern Pacific Railway to Jennings.

Lafayette, 0.30 mile west of; road crossing.....39.3
Lafayette, 0.9 mile west of; road crossing at cattle guards 146 B-C.....41.7
Lafayette, 1.5 miles west of; road crossing at cattle guards 147 A-B.....40.8

Lafayette, 1.61 miles west of; telegraph pole south of track, spike in base of 37.02
Lafayette, 1.60 miles west of; cattle guard 147 B, 125 feet west, 48 feet north of track, in angle of road, iron post stamped "37 LA" 37.333
Lafayette, 2.4 miles west of; road crossing at cattle guards 148 A-B 41.4
Lafayette, 2.62 miles west of; signal tower No. 1485, 230 feet east of; telegraph pole, spike in base of 39.07
Scott station, 2.80 miles east of; road crossing at cattle guards 148 D-E 40.0
Scott, 1.86 miles east of; south of track, spike in base of telegraph pole 35.21
Scott station, 0.9 mile east of; road crossing at cattle guards 150 A-B 37.0
Scott station, 0.58 mile east of; signal tower No. 1505, 340 feet east of; south of track, spike in base of telegraph pole 34.03
Scott station, section yard northwest of; in southeast corner of; iron post stamped "36 LA" 36.410
Scott, in front of station; top of rail 36.2
Scott, 1.1 miles west of; railroad track at mile-post 151; spike in base of east post 36.35
Scott station, 2.1 miles west of; mile-post 152, spike in base of 32.16
Duson, 2.11 miles east of; mile-post 153, 200 feet west of; south of track, spike in base of telegraph pole 33.22
Duson, 2 miles east of; road crossing at cattle guards 154 B-C 37.1
Duson, 1 mile east of; 12.5 feet south of track, opposite mile to sta. post, iron post stamped "33 LA" 32.872
Duson, in front of station; top of rail 37.1
Duson, northwest corner of station, 25 feet west of; 50 feet north of track, iron post stamped "No. 36—35 feet—LA" 35.217
Duson, 1 mile west of; mile-post 156, 720 feet west of; spike in base of telegraph pole 30.410
Duson, 1.6 miles west of; road on parish line, top of rail 35.0
Duson, 1.6 miles west of; 20 feet west of public highway,

15 feet south of track, iron post stamped "32 LA"....32.179
Rayne, 2.48 miles east of station; spike in base of telegraph pole....29.78
Rayne, 1.06 miles east of; south of track, spike in base of telegraph pole....31.58

CROWLEY QUADRANGLE.

Rayne, 0.40 mile east of; at crossing of O. G. & N. R. R., top of rail....35.8
Rayne, in front of station; top of rail....35.6
Rayne, section yard northwest of, southeast corner of; iron post stamped "No. 37, 32 LA"....31.673
Rayne, 1.45 miles west of; south of track and near signal tower, spike in base of telegraph pole....27.65
Rayne, 2.63 miles west of; mile-post No. 163, 480 feet east of; south of track, spike in base of telegraph pole....25.36
Rayne, 3.10 miles west of; road crossing at cattle guards 164 A-B....28.4
Rayne, 3.7 miles west of station; road crossing....27.3
Rayne, 3.71 miles west of; public highway crossing, 12 feet east of; 12 feet south of track, 90 feet west of mile-post 164, iron post stamped "25 LA"....25.189
Crowley, 2.5 miles east of; spike in base of milepost 165....23.23
Crowley, 1.3 miles east of; spike in base of mile-post 166..21.70
Crowley, 0.8 miles east of; crossing of Avenue J with S. P. R. R., top of rail....24.10
Crowley, in front of station; top of rail....23.8
Crowley, crossing of Parkinson avenue, 40 feet west of; 24.5 feet south of track, iron post stamped "No. 38, 24 LA"....23.760
Crowley, 1.16 miles west of; mile to station post (near mile-post 168), spike in base of....21.29
Crowley, 1.2 miles west of; road crossing, top of rail....23.0
Crowley, 2.2 miles west of; north right of way line of track (opposite mile-post 169), iron post stamped "19 LA"....18.610
Crowley, 3.41 miles west of; highway crossing, 100 feet west of; spike in base of telegraph pole....18.46
Crowley, 3.41 miles west of; highway crossing, top of rail..20.7

Crowley, 4.17 miles west of; mile-post 171, spike in base of.15.18
Estherwood, 1.15 miles east of; road crossing.....19.4
Estherwood, 0.85 mile east of; mile-post 172, spike in base of 16.39
Estherwood, in front of station, 33 feet north of track, iron post stamped "17 LA".....16.484
Estherwood, in front of station; top of rail.....19.4
Estherwood, 0.45 mile west of; road crossing.....20.0
Estherwood, 1.6 miles west of; spike in base of telegraph pole 17.0
Midland, railroad crossing, telegraph pole in southwest angle, spike in base of.....15.25
Midland station, railroad crossing, top of rail.....19.3
Midland, 400 feet east of station; main line S. P. R. R., 35 feet south of; iron post stamped "14 LA".....14.351

JENNINGS QUADRANGLE.

Midland, 1.2 miles west of; signal tower No. 1762; 400 feet east of, telegraph pole south of track, spike in base of..15.52
Midland, 1.5 miles west of; top of rail at road crossing.....19.2
Midland, 2.5 miles west of; road crossing at cattle guards 178 B-C 16.9
Mermentau, 2.4 miles east of; spike in base of telegraph pole 15.27
Mermentau, 1.7 miles east of; road crossing, top of rail.....18.0
Mermentau, 1.3 miles east of; mile-post 179, 135 feet east of; 60 feet north of track, iron post stamped "10 LA" 10.397
Mermentau, 0.6 mile east of; road crossing, at cattle guards, 180 B-C 16.3
Mermentau, top of rail at station.....16.8
Mermentau, 190 feet west of; 35 feet south of south rail, iron post stamped "No. 41, 13 LA".....12.773
Mermentau, 0.5 mile west of; signal tower No. 1808; 250 feet west of; spike in base of telegraph pole.....13.39
Mermentau, 0.7 mile west of; road crossing at Silverwood Grocery store 17.2
Mermentau, 1.7 miles west of; mile-post 182, 175 feet east of; spike in base of telegraph pole.....11.88

Mermentau, 2.8 miles west of; 400 feet east of road crossing; south of track, spike in base of telegraph pole....17.70
Jennings, 2.25 miles east of; public highway crossing, 25 feet east of, 65 feet north of track, iron post stamped "18 LA" 18.284
Jennings, 2.25 miles east of; road crossing..... 21.1
Jennings, 1.1 miles east of station; 180 feet east of station mile-post, spike in base of telegraph pole..... 19.48
Jennings, in front of station; top of rail..... 30.1
Jennings (old station), 300 feet west of; 55 feet south of track, 14 feet west of sidewalk, iron post stamped "No. 42, 29 ft. LA"..... 29.010
Jennings, 0.40 mile west of; signal tower No. 1818, 115 feet west of; 25 feet north of track, iron post stamped "25 LA" 25.385

CO-OPERATIVE WORK IN PRIMARY TRAVERSE.

(Notes furnished by the Computing Division U. S. Geol. Survey.)

Abbeville, Calumet, Crowley Delcambre, Jeanerette, Lafayette, Jennings and New Iberia Quadrangles.

Acadia, Iberia, Lafayette, St. Martin, St. Mary and Vermilion Parishes.

The following geographic positions were determined by primary traverse by Mr. L. E. Tucker, topographic aid, in the fall of 1906. The line begins with the position of the Pilgrim Baptist church at Morgan City, as given by the U. S. Coast and Geodetic Survey, and follows the Southern Pacific Railroad to New Iberia, thence checking back along the same route, at Morgan City. From New Iberia the line continues along the Southern Pacific Railroad via Lafayette and Crowley to Midland. From Midland the line follows the Louisiana & Western, Iberia and Vermilion branch of the Southern Pacific Railroad south and east via Gueydan and Abbeville, checking at New Iberia. A line was also run along the Southern Pacific Railroad from Midland to Jennings, checking back at Midland. This work was done by the U. S. Geological Survey in co-operation with the State of Louisiana, the latter being represented by Prof. G. D. Harris, in charge of the State Survey.

CALUMET QUADRANGLE.

Geographic Positions Along the Southern Pacific Railroad Between Morgan City and Lafayette.

STATIONS—	LATITUDE.			LONGITUDE.		
	°	′	″	°	′	″
Morgan City, Pilgrim Baptist Church.	29	41	34.53	91	12	26.18
Morgan City, in northwest corner of the Morgan City Catholic Church yard, 88 feet north of northwest corner of church, iron post stamped "Prim. Trav. Sta. No. 23, 1906, LA"	29	41	42.31	91	12	19.83
Lagonda station, road crossing	29	40	50.93	91	16	23.64
Patterson station, 1 mile east of; road crossing	29	40	46.61	91	17	34.85
Patterson station, road crossing	29	41	19.29	91	18	26.63
Calumet station, rail opposite ticket office window	29	41	52.59	91	21	57.82
Calumet station, 76 feet east of station platform, 27 feet north of Southern Pacific Railroad, iron post stamped "Prim. Trav. Sta. No. 24, 1906, LA"	29	41	52.76	91	21	56.29
Recohoc water tank, point on rail opposite	29	42	33.85	91	23	31.62
Recohoc water tank, 2.4 miles northwest of; road crossing	29	43	52.22	92	25	27.12
Bayou Sale station, point on rail opposite ticket office	29	44	28.23	91	26	20.30

GRAND LAKE QUADRANGLE.

STATIONS—	LATITUDE.			LONGITUDE.		
	°	′	″	°	′	″
Bayou Sale station, 1.2 miles northwest of; road crossing	29	45	05.73	91	27	15.62
Garden City station, point on rail opposite ticket office	29	45	38.20	91	28	03.56
Garden City station, 0.9 miles northwest of; road crossing	29	46	06.72	91	28	45.65
Garden City station, 2 miles northwest of; road crossing	29	46	40.00	91	29	34.80

JEANERETTE QUADRANGLE.

STATIONS—	LATITUDE.			LONGITUDE.		
	°	′	″	°	′	″
Franklin station, set on west side of Southern Pacific Railroad, in section house yard 80.5 feet southwest of station, 60 feet west of track, standard bench-mark post stamped "Prim. Trav. Sta. No. 25, 1906, LA"	29	47	26.24	91	30	25.23
Franklin, crossing of railroad and New Iberia street	29	47	51.50	91	30	50.15
Franklin station, 2 miles northwest of; railroad crossing	29	49	10.40	91	32	09.53
Baldwin station, point on rail opposite ticket office	29	50	08.62	91	33	07.75
Baldwin station, 100 feet northwest of; 25 feet west of center of highway, 15 feet south of switch, iron post stamped "Prim. Trav. Sta. No. 26, 1906, LA"	29	50	08.87	91	33	09.38
Baldwin station, 2.6 miles northwest of; road crossing	29	51	50.22	91	34	49.32
Adeline station, point on track opposite ticket office	29	52	32.08	91	35	31.99
Adeline station, 220 feet west of; 20 feet north of track, iron post stamped "Prim. Trav. Sta. No. 27, 1906, LA"	29	52	33.83	91	35	34.03
Adeline station, 1.7 miles northwest of; road crossing	29	53	09.69	91	36	43.56
Abavila plantation refinery, road crossing opposite	29	54	15.00	91	39	11.17
Jeanerette station, crossing of railroad and St. Peter's street, line between St. Mary and Iberia parishes and city limits of Jeanerette	29	54	28.49	91	39	31.12
Jeanerette station, 0.8 mile east of; at city limits, 45 feet north of north track and 30 feet east of center of highway which is St. Mary-Iberia parish line, iron post stamped "Prim. Trav. Sta. No. 28, 1906, LA"	29	54	28.78	91	39	50.64
Jeanerette station, point on rail opposite ticket office	29	54	51.00	91	40	11.78
Jeanerette station, 1 mile northwest of; road crossing	29	55	26.35	91	41	00.21
Loisel Sugar Plantation, tram road crossing	29	56	06.16	91	41	54.75

DELCAMBRE QUADRANGLE.

STATIONS—	LATITUDE.			LONGITUDE.		
	°	′	″	°	′	″
Olivier station, 54 feet west of; 25 feet north of track, iron post stamped "Prim. Trav. Sta. No. 29, 1906, LA"	29	58	33.80	91	45	18.40
Olivier station, point on rail opposite ticket office	29	58	32.84	91	45	17.94
Olivier station, 1.8 miles northwest of; road crossing	29	59	18.22	91	46	52.31
New Iberia, at south edge of; road crossing, at city limits	29	59	42.95	91	48	03.03

Geographic Positions Along the Southern Pacific Railroad (Louisiana Western, Iberia and Vermilion Branch) Between Delcambre and New Ibearia.

STATIONS—	LATITUDE.			LONGITUDE.		
	°	′	″	°	′	″
Delcambre station, on west side of road crossing on Iberia-Vermilion parish line, 33 feet north of track, 25 feet west of highway, iron post stamped "Prim. Trav. Sta. No. 48, 1906, LA"	29	57	08.68	91	59	17.67
Delcambre station, road crossing on Iberia-Vermilion parish line	29	57	08.34	91	59	17.54
Bob Acres, just west of; road crossing.	29	56	57.77	91	58	00.51
Lee station, 1.3 miles west of; road crossing	29	56	39.71	91	55	48.86
Lee station, road crossing	29	56	29.20	91	54	32.21
Rynella station, road crossing	29	56	38.26	91	53	02.48
Veria station, point on rail opposite station sign	29	56	57.92	91	52	30.80
Veria station, opposite station sign, 35 feet south of track, iron post stamped "Prim. Trav. Sta. No. 49, 1906, LA"	29	56	57.81	91	52	30.54
Mile-post 4, road crossing	29	57	51.04	91	51	57.21
Veria station, 3 miles east of; road crossing	29	59	10.63	91	50	46.83

CROWLEY QUADRANGLE.

STATIONS—	LATITUDE.			LONGITUDE.		
	°	′	″	°	′	″
Rayne station, in southeast corner of section house yard, 50 feet north of track, 8 feet inside of fence corner, just back of red tool house, iron post stamped "Prim. Trav. Sta. No. 37, 1906, LA"	30	14	11.80	92	16	10.36
Rayne station, 2 miles west of; private road crossing	30	14	11.79	92	18	11.82
Mile-post 164, road crossing	30	13	39.13	92	19	42.66
Hunter Rice Mill, road crossing east of T. 10 S., R. 1 E, Secs. 3 and 4, north corner of	30	12	47.44	92	21	45.75
	30	12	51.70	92	21	45.75
Crowley station, about 125 feet southwest of; 40 feet west of center of Parkerson avenue, 24.5 feet south of center of main track, iron post stamped "Prim. Trav. Sta. No. 38, 1906, LA"	30	12	35.45	92	22	13.83
Mile-post 168, road crossing	30	12	09.18	92	23	16.79
Crowley, 3.4 miles west of; road crossing	30	11	18.42	92	25	17.54
Estherwood, 1 mile east of; road crossing	30	10	53.52	92	26	48.55
Estherwood station, 35 feet north of track, iron post stamped "Prim. Trav. Sta. No. 39, 1906, LA"	30	10	53.12	92	27	52.07
Midland station, crossing of railroads, 485 feet east of; 35 feet south of tracks, iron post stamped "Prim. Trav. Sta. No. 40, 1906, LA"	30	10	51.00	92	29	52.96
Midland station, road crossing (Southern Pacific)	30	10	51.28	92	29	58.43

Geographic Positions Along Southern Pacific Railroad (Louisiana Western, Iberia and Vermilion Branch) Between Midland and Kaplan.

STATIONS—	LATITUDE.			LONGITUDE.		
	°	′	″	°	′	″
Morse station, point on rail opposite semaphore	30	07	23.61	92	29	51.27
T. 11 S., R. 1 W., corner secs. 5, 6, 7 and 8, crossroads	30	06	39.64	92	29	51.77
Wright postoffice, road crossing	30	00	28.79	92	25	42.40
T. 12 S., R. 1 W., corner secs. 11, 12, 13 and 14, crossroads	30	00	29.29	92	25	42.40
T. 12 S., R. 1 E., secs. 7 and 18, T. 12 S., R. 1 W., secs. 12 and 13, corner of, crossroads	30	00	29.61	92	24	42.23
Mulvey flag station, 48 feet south of; set on east side of railroad, 50 feet west of road crossing, iron post stamped "Prim. Trav. Sta. No. 45, 1906, LA"	30	00	25.08	92	24	11.28
Mulvey station, 1 mile east of; road crossing (37 C D)	30	00	22.88	92	23	09.40
Mulvey station, 2.2 miles east of; irrigation canal (36 B)	30	00	23.40	92	22	09.65
Kaplan station, 3.5 miles west of; road crossing	30	00	25.08	92	20	36.47
Kaplan station, 1.5 miles west of; road crossing	30	00	19.13	92	18	32.46
Kaplan station, point on rail opposite station semaphore	29	59	54.17	92	17	08.49
Kaplan station, opposite station semaphore, 45 feet south of track and 18 feet east of telegraph pole, iron post stamped "Prim. Trav. Sta. No. 46, 1906, LA"	29	59	53.75	92	17	08.66
Kaplan station, 1.6 miles east of; irrigation canal	29	59	27.37	92	15	38.31

JENNINGS QUADRANGLE.

Geographic Positions Along Southern Pacific Railroad Between Midland and Jennings.

STATIONS—	LATITUDE.			LONGITUDE.		
	°	′	″	°	′	″
Midland station, 2.5 miles west of; road crossing	30	10	49.42	92	32	31.44
Mermentau station, 1.8 miles east of; road crossing (179 C)	30	10	49.84	92	33	34.09
Mermentau station, 190 feet west of; 35 feet south of north rail, iron post stamped "Prim. Trav. Sta. No. 41, 1906, LA"	30	11	20.60	92	35	16.10
Mermentau Draw Bridge, east end of and Acadia-Calcasieu parish line	30	11	23.04	92	35	22.70
Jennings station, on south side of Southern Pacific Railroad, on west side of first crossing west of old passenger station, 10 feet west of sidewalk and 55 feet south of main line of railroad, iron post stamped "Prim. Trav. Sta. No. 42, 1906, LA"	30	13	17.72	92	39	31.72

Geographic Positions Along Southern Pacific Railroad (Louisiana Western, Iberia Branch) Between Bayou Queue de Tortue and Gueydan.

STATIONS—	LATITUDE.			LONGITUDE.		
	°	′	″	°	′	″
Bayou Queue de Tortue, east end of bridge over; Acadia-Vermilion parish line..	30	04	56.71	92	30	19.83
Bayou Queue de Tortue, 1.7 miles south of; irrigation canal.....	30	03	41.96	92	30	50.74
Gueydan, station, point on rail opposite semaphore	30	01	36.34	92	30	50.56
Gueydan station, opposite station semaphore, 35 feet west of south rail of main track, iron post stamped "Prim. Trav. Sta. No. 44, 1906, LA".....	30	01	36.34	92	30	50.96
Gueydan station, 0.9 mile south of; road crossing (45 B C).....	30	00	49.78	92	30	49.51

ABBEVILLE QUADRANGLE.

Geographic Positions Along Southern Pacific Railroad (Louisiana Western, Iberia Branch) Between Nunez Station and Erath Station.

STATIONS—	LATITUDE.			LONGITUDE.		
				°	′	″
Nunez station (postoffice), road crossing	29	59	05.92	92	13	37.55
Lastie station, point on rail opposite section house No. 405.....	29	58	55.18	92	12	18.12
Lastie station, 0.9 mile east of; road crossing (25 B C).....	29	58	48.32	92	11	27.40
Abbeville station, 58 feet west of; 29 feet north of track, iron post stamped "Prim. Trav. Sta. No. 47, 1906, LA".	29	58	19.98	92	08	25.18
Cotton gin, road crossing.....	29	58	16.61	92	08	02.00
Youngs station, road crossing.....	29	58	07.88	92	06	58.12
Gross Isle station, road crossing.....	29	57	58.00	92	05	26.65
Aristide's switch, road crossing.....	29	57	41.82	92	03	22.28
Erath station, 3770 feet east of; road crossing	29	57	25.24	92	01	21.13

NEW IBERIA QUADRANGLE.

STATIONS—	LATITUDE.			LONGITUDE.		
	°	′	″	°	′	″
New Iberia station, point on rail opposite ticket office	30	00	33.49	91	49	25.41
New Iberia station, 105 feet west of water standpipe and 55 feet south of railroad watertank, iron post stamped "Prim. Trav. Sta. No. 0, 1906, LA"	30	00	31.49	91	49	25.40
Segura station, point on rail opposite station sign post	30	02	14.20	91	51	18.12
Burke, 1 mile south of; road crossing	30	03	03.72	91	52	14.81
Burke station, on east side of railroad 28 feet from same and on south side of road at corner of road and railroad right of way fence, 100 feet southeast of station, iron post stamped "Prim. Trav. Sta. No. 31, 1906, LA"	30	03	44.82	91	52	53.84
Burke station, 880 feet northwest of; crossing of Iberia-St. Martin parish line	30	03	52.39	91	53	00.59
Cades station, point on rail opposite ticket office	30	05	04.87	91	54	06.21
Duchamp crossing station, on southwest corner of road, 35 feet south of track, iron post stamped "Prim. Trav. Sta. No. 32, 1906, LA"	30	06	10.41	91	55	05.23
T. 11 S., R. 5 E. (southwestern district La.), corner secs. 41, 12 and 42	30	06	05.60	91	55	21.27
Duchamp station, 1.6 miles northwest of; Lafayette-St. Martin's parish line, road crossing	30	07	14.27	91	56	03.49
Billeaud switch, road crossing	30	08	06.28	91	56	50.66
Broussard station, in northeast corner of section house yard, iron post stamped "Prim. Trav. Sta. No. 33, 1906, LA"	30	09	03.24	91	57	42.73
Landrys switch, point on rail opposite station sign	30	10	36.09	91	59	03.55

LAFAYETTE QUADRANGLE.

STATIONS—	LATITUDE.			LONGITUDE.		
	°	′	″	°	′	″
Landrys switch, 2.3 miles northwest of; road crossing	30	12	21.66	92	00	07.71
Lafayette station, in northwest corner of freight house yard about 240 feet north of passenger station and about 30 feet south of track, iron post stamped "Prim. Trav. Sta. No. 34, 1906, LA"	30	13	43.14	92	00	50.98

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Geographic Positions Along the Southern Pacific Railroad Between Lafayette and Rayne Station.

STATIONS—	LATITUDE.			LONGITUDE.		
	°	′	″	°	′	″
Lafayette station, 1 mile west of; road crossing	30	14	08.29	92	01	28.85
Scott station, 2.9 miles east of; road crossing	30	14	08.62	92	02	57.94
Scott station, 1 mile east of; road crossing	30	14	09.08	92	04	48.13
Scott station, in southeast corner of section house yard opposite station, 30 feet north of track, 2 feet inside fence corner, iron post stamped "35, 1906, LA"	30	14	09.50	92	05	41.98
Duson station, 2 miles east of; road crossing (154 C)	30	14	09.87	92	09	00.44
Duson station 25 feet west of the northwest corner of station, 50 feet north of track, in southwest corner of field, iron post stamped "Prim. 36, 1906, LA"	30	14	10.66	92	10	57.85
Duson station, 1.6 miles west of; Lafayette-Acadia parish line, road crossing	30	14	10.51	92	12	35.37
Rayne station, 1.2 miles east of; road crossing	30	14	10.94	92	14	53.19

THE JENNINGS SHEET.

By consulting the map (Pl. XI) it will be observed that the area here spoken of as the "Jennings Sheet" does not correspond to the "Jennings Quadrangle" of the notes furnished by the Computing Division of the U. S. Geol. Sur. (See pp. 15 & 20). The reason for this is that the area shown is more or less of a unit, topographically and commercially. Here, located centrally on our sheet, is the junction of the three large bayous forming the Mermentau River. Here just above the center is the famous Jennings Oil Field, with the important and flourishing town of Jennings and the Oil Refinery to the west, and the village of Egan with its loading racks to the east. Now, on the regular 15′ quadrangles Jennings and the Jennings Oil Field come on different plates, for 30° 15′ passes between the two. We fully realize, however, that there is a great deal to be gained by uniformity in publication and that the U. S. topographic sheets must be 15′ or 30′ quadrangles. Yet, till this area is taken up by that organization we feel sure that the form of our map is quite preferable. There can be no great loss, however, for the data here

presented may be quickly transferred onto the regular 15′ quadrangular forms.

Again, it will be observed that whereas the usual contour intervenes on the U. S. topographic sheets is 20 or 50 feet, it is here but 5 feet. The reason for this is that the country is so flat that a twenty-foot contour map would be almost worthless. The area represented ranges in height from about 3 to 33 feet above sea level, therefore there would be but one contour line (the 20 foot), if the interval were 20 feet as usual (and as shown on the Winnfield Sheet). To be of most service in rice culture and levee and canal construction the contour interval should be but about two feet; but time and funds have not permitted map work of such detail; but it is hoped the results of our work embodied in the accompanying sheet with its 5-foot contours will be found of considerable real service to the people dwelling in this region.

There is one more point that needs special mention. That is the differentiation on the map of the wooded from the prairie areas. This has been done not only to show to what extent the region is wooded, but to show the distribution of soils upon which trees will grow and the distribution of soils that ae not adapted to forest growth—in other words, the prairie soils.

Details regarding the soils in general of the eastern part of this area can be obtained by writing the Bureau of Soils, Agricultural Department, Washington, D. C., for the report on the soils of Acadia Parish, La. A map therein shows the distribution of soils in that parish. For details regarding the deep well water supply for domestic and irrigation purposes (See Bull. 1, Geol. Surv. La.). Since that bulletin was written there has been a gradual increase in dependence upon irrigation waters furnished by large companies and obtained almost wholly from the bayous traversing the region.

The geology of the Jennings Oil Field will be found in a forthcoming Bulletin.

Bulletin No. 7 Report of 1907

Geological Survey of Louisiana

GILBERT D. HARRIS, Geologist in Charge

ROCK SALT

Its Origin, Geological Occurrences and Economic Importance In

The State of Louisiana

TOGETHER WITH

Brief Notes and References to All Known Salt Deposits and Industries of the World

By G. D. HARRIS,
Assisted by C. J. MAURY and L. REINECKE

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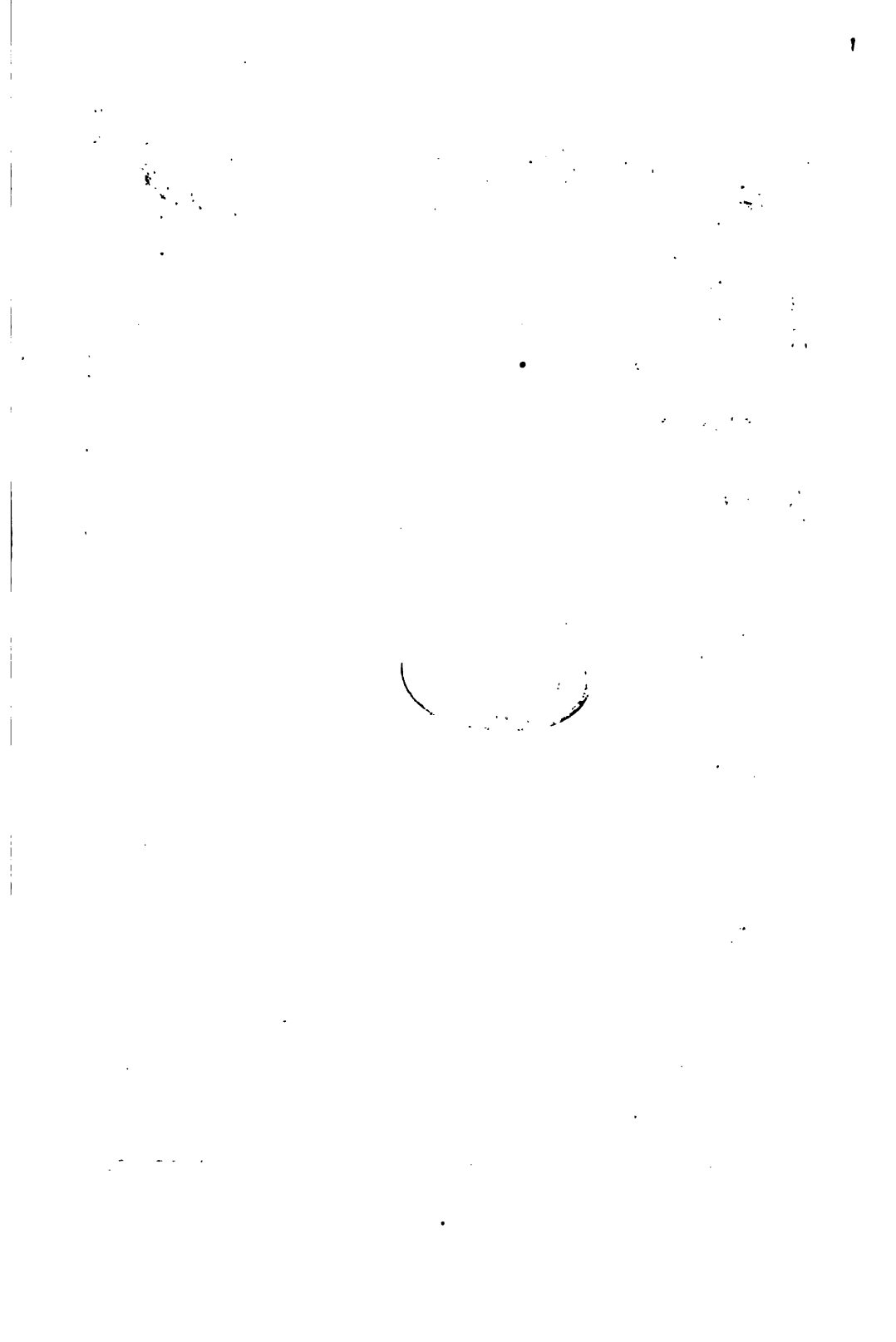
1908.



LARGE SALT MASSES, ON PLATFORM AT MYLES SALT WORKS, WEEKS, LA. HARRIS PHOTO

p. I-XI Index bound at end of vol.

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Louisiana State University and A. & M. College

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PREFATORY REMARKS.

The salines of North Louisiana have long been known. Even before the advent of the white man, Indians used to resort to these places to obtain their salt. In colonial days, salt from the salines supplied but a local demand. During the Civil War, however, when communication between this and distant lands was well nigh cut off, the salines became of great importance and were made to yield thousands of tons of salt annually. When peace was again established and communication became easier and easier by ever increasing railway facilities, salt was imported, and the old salines lapsed into insignificance. Again the tide should turn and North Louisiana should become one of the important salt producing districts of the world. Now we know, what two years ago could only be surmised, that beneath some if not all of the salines occur vast masses of rock salt, hundreds if not thousands of feet in thickness.

In South Louisiana, at Petite Anse, the drill shows 2263 feet to be the thickness of the superficial lens of salt; but after 70 feet of foreign matter are passed the drill again enters rock salt of unknown thickness. Engineer Bradford at this place writes: "I estimate the salt deposit actually located to amount to about 2,000,000,000 tons." A very similar salt mass is known to occur beneath Grande Côte. On Côte Carline the drill entered salt at 334 ft. and continued in salt without change till drilling ceased at a depth of 2090 ft. Belle Isle has its underlying mass of salt as well as sulphur and oil; so, too, has Anse-la-Butte.

While the new commercial South is awakening to an appreciation of its vast and almost untouched natural resources; while drilling and mining methods are improving and perfecting; while the oceans are being united at Panama; while the Mississippi is being looked to as a feasible channel for sea-going vessels; while the number of inhabitants of this country is rapidly increasing; while new uses and new demands for salt

are constantly multiplying; no one can claim to have but the faintest idea of the true value of the huge masses of pure rock salt stored away beneath the "islands" and salines of Louisiana.

With complete assurance as to a satisfactory amount of salt in Louisiana, one naturally turns next to questions of quality, or rather comparative quality, best methods of winning, transportation rates, domestic and foreign markets, production of foreign countries, import, export duties, etc. No one volume could contain all the information that one might feel the need of in attempting to develop on a large scale the salt industry of Louisiana. It is hoped, however, that the references given in this Bulletin, together with the very brief, sketchy remarks that appear in the text may serve as a guide to where information relating to any phase of the salt industry of the world can be obtained. In German and in French there are works that cover somewhat this same ground. The geological occurrence of salt at different localities is, however, often very indifferently stated. We have found no recent English work on the subject.

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CHAPTER I.

SALT IN LOUISIANA, WITH SPECIAL REFERENCE TO ITS GEOLOGIC OCCURRENCE,

BY G. D. HARRIS.

Details of Salt Mines and Salt Prospects in Louisiana and Southeast Texas.

PART I: Localities where salt is now being mined.

GRAND CÔTE (WEEKS ISLAND.)

Location, Size and Form.—This island, so-called, is located on the eastern shore of Weeks Bay, an eastern lobe of Vermillion Bay. Its general position relative to the other "islands" can be well seen by consulting Pl. XXIV of this Bulletin, or better still, by turning to Pl. XVII of Bulletin No. 3, opposite p. 17. It is easily reached by rail, by leaving the main line of the Southern Pacific at Franklin or Baldwin, taking then the Cypremort branch to the west. Although styled Grande Côte on account of its great size, it is scarcely two miles in diameter. Its form and height are shown on Pl. XIII of this report.

History of Mining Operations.—According to Veatch's Report ('99), prospecting for salt was begun in March, '97; salt was discovered in July of the same year and in March, '98 the Myles Salt Company was organized; and, after more prospecting with the drill, in July, '98, the location of a shaft was determined upon. This shaft had reached the salt at the time Veatch visited the island. One hundred feet of 10 ft. tubular casing were used in sinking the shaft to the salt mass. Below this, in July, '01, work was begun sinking a rectangular shaft into the rock salt. In March, '02, the 600 ft. level was reached and tunnels east and west were being driven. The extreme depth of the shaft is 645 feet. For further details regarding the mine and mining operation, see below.

Geology.—This is a typical salt "island." Its geology so far as we are able to make out, is entirely dependent upon the great mass of rock salt forming beneath its few feet of superficial sands, clays and gravels.* Naturally, where very recent, unconsolidated sands and clays constitute the superficial beds in a region not remarkably rugged, there are very few good outcrops. When the streams cut down the soft, yielding materials, the banks cave and the typical V-shaped valley is ever maintained; rank vegetation soon blankets what might otherwise be a temporary outcrop. It is evident, however, that the uppermost bed on the island is of loamy clay, of a generally yellowish hue. This can be seen well about the Weeks residence and on the road to the Sugar House, going from the Salt Mine. Again, the records of 44 wells usually begin with clay, varying from a few feet up to 60 or more in thickness. In the ravines about one-fourth of a mile to the northeast of well No. 13, beds lower down in the scale may be seen. These consist of sands, often highly ferruginous, chert pebbles in sand, and gray sandy clays, all tilted up at various angles and directions. The various well sections given below, it will be noticed show gravelly and sandy layers sometimes several hundred feet thick. When salt is met with, it is apt to be immediately overlain with a few feet of clay, though this is by no means always the case.

The salt mass of this island comes nearest the surface in the vicinity of the mine, slopes very abruptly to the west and south, more gently to the east, and but slightly to the north, being but 275 ft. down at well No. 4 in the vicinity of the Weeks residence.

Great irregularities are known to occur in the upper surface of the salt. Observe the topography shown by the green lines on Plate XIV. Note, too, how little there is in common between the minor soil surface details and the irregularities of the surface of the salt mass. Still, too much stress must not be laid on this point until more borings have been made in all parts of the island, borings, too, sufficiently deep to reach the salt wherever it exists.

*Consult Bull. No. 3, Rept., '05, for location of bench marks and the establishing of a tide gage for the purpose of ascertaining the rate and manner of growth of this island's mass.

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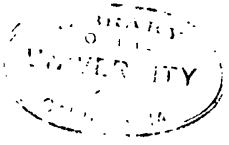


Thus far we have little proof as to the cause of the irregularities of the salt mass. It might well be supposed that at some remote time the mass had been more elevated than now, even considerably above sea level. Rain water percolating through the overlying sands and clays would finally reach the salt and by dissolving it, huge underground channels and finally caves might be formed. These would soon be refilled owing to the unconsolidated character of the overlying beds, and finally very much disturbed masses of clay and sand would cover in a very irregular manner the much diversified surface of the salt. Subsequently, a sinking of salt and all would have to be postulated in order to bring the salt to its present lowly position—from 40 to several hundred feet below sea level. Another explanation seems to us more probable. Note in Pl. XXII the direction of "streaks." These streaks, it may be said in passing, are not caused by any dark substance in the salt, but by the absorption of the rays of light by minute particles of seemingly clear anhydrite. This is proven first by dissolving some of the streak salt in fresh water and noting the "sand," as the miners say, that settles at the bottom, and again by chemical analysis as shown on p. .
To the south and east of the shaft these streaks show that the planes in which they lie are nearly vertical, and extend in a direction more or less parallel to the southern flank of the salt mass as indicated on Plate XIV. To the north and northeast of the shaft (Fig. 7) the strike of the streaks, if the expression be permissible, is various, but in a general way more or less

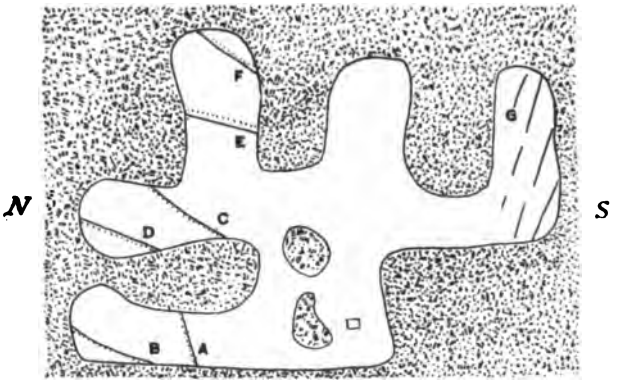


FIG. 7. PLAN OF MYLES MINE, SHOWING DIRECTION OF STREAKS, WEEKS, LA.

parallel, with the west flank of the salt mass. Whether these streaks be looked upon as indication of original bedding planes or as due to infiltration of anhydrite bearing solutions after the salt mass was more or less formed, it seems to us that although they are most erratic in their behavior, twisting, folding and forming all sorts of figures, even circles, as seen in cross section,

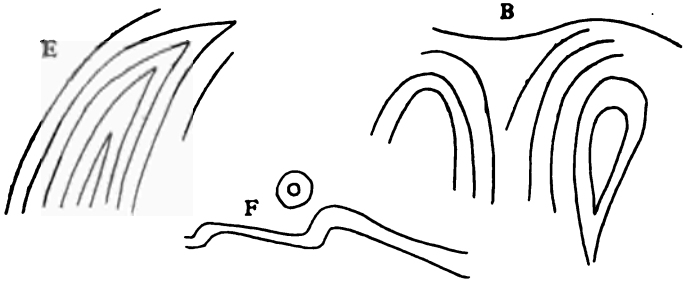


FIG. 8. VARIOUS TYPES OF STREAKS SEEN IN MYLES SALT MINE, WEEKS, LA.

Fig. 8, their general directions, as stated above, more or less parallel to the nearest flank of the salt mass, would indicate that the form of the mass has something in common with the formation of the streaks. In other words, the salt mass was made in

FRONT VIEW OF THE MYLES SALT CO'S MILL, WEEKS, LA. HARRIS PHOTO

somewhat its present shape, and its main configuration is due accordingly not to the work of erosion or subterranean solution.*

Besides the planes of streaks just described there are planes of weakness in the salt mass running very nearly horizontally, horizontal joints as perhaps they may be called. When a drift has been undercut for some distance, the roof sometimes drops down in huge masses, leaving large expanses of smooth, very nearly horizontal ceiling. These planes of weakness we do not interpret as indicating original bedding, but as having been generated by vertical pressure more or less after the manner of slaty cleavage.

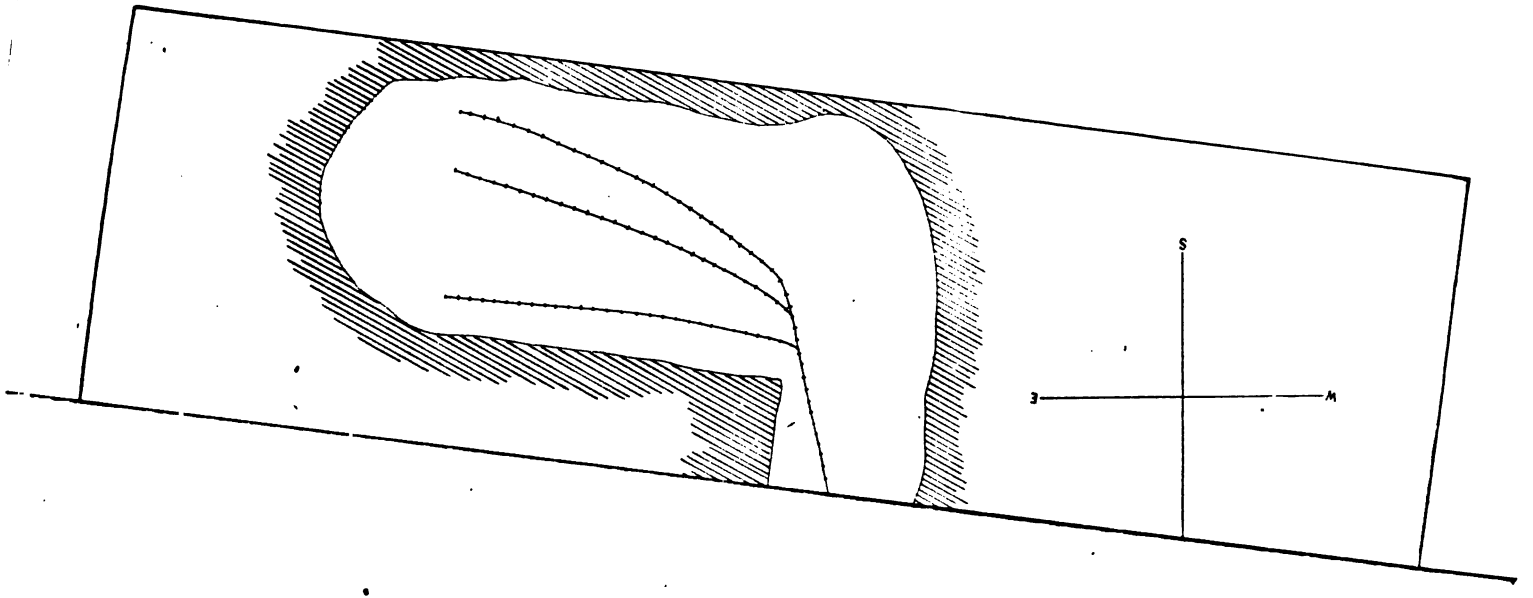
Before leaving the topic *Geology* we must insert the records of over 40 test wells that have been put down on the island for the purpose of ascertaining the form, or topography of the upper surface of the salt. The exact location of these wells is indicated on the ground by posts bearing the numerals herewith affixed.

Well Sections on Grande Côte.

1. Clay, 30 ft.; sand, 185; gravel, 5; sand, 25; no salt.
2. Sand, 175 ft.; no salt.
3. Clay, 38 ft.; sandy clay, 100; gravel, 80 ft.; no salt.
4. Clay, 20 ft.; sand and gravel, 240; clay, 15 ft.; salt at 275 ft.
5. Depth, 150 ft.; no salt.
6. Sand and clay, 385 ft.; no salt.
7. Clay, 5 ft.; sand, 105 ft.; no salt.
8. Clay, 25 ft.; sand, 180; salt at 205 ft.
9. Clay, 35 ft.; gravelly sand, 1.2 ft.; salt at 147 ft.
10. Mainly sand, 180 ft. to salt.
11. Clay, 10 ft.; sand, 170 ft.; no salt.
12. Clay, 10 ft.; sand, 130 ft.; gravel, 22 ft.; salt at 162 ft.
13. Clay, 15 ft.; gravelly sand, 165 ft.; black clay, 5 ft.; salt at 195 ft.
14. Wind mill, water well; clay, 10 ft.; sand, 35 ft.; gravel, 15 ft.; no salt.
15. Clay, 18 ft.; sand, 140 ft.; salt at 158 ft.
16. Sandy clay, 145 ft. to salt; salt for at least 600 ft.
17. Clay, 10 ft.; gravelly sand, 135 ft.; salt at 145 ft.
18. About 150 ft. to a gravel bed 12 ft. thick; salt at 162 ft.
19. Clay, 18 ft.; sand, 210 ft.; no salt.
20. Clay, 16 ft.; sand, 194 ft. to salt, 210 ft.
21. Definite section not known; about 165 ft. to salt.
22. Clay, 60 ft.; sand, 90 ft.; clay, 10 ft.; salt at 160 ft.
23. Clay, 15 ft.; sand, 28 ft.; clay, 12 ft.; gravel, 10 ft.; sand, 20 ft.; gravel, 20 ft.; sandy gravel, 17 ft.; sand, 34 ft.; black clay, 4 ft.; salt at 160 ft.

*Consult Plates XXII, XLVIII and LIII for an idea of streaks or bands in salt masses.

24. Clay, 16 ft.; sand, 47 ft.; gravel, 20 ft.; sand, 55 ft.; gravel, 12 ft.; salt at 150 ft.
25. Sand, 100 ft.; gravel, 10 ft.; salt at 110 ft.
26. Alternating sand and clay beds to 36 feet; sand, 132 ft.; salt at 169 ft.
27. Clay, 12 ft.; sand, 165 ft.; salt at 177 ft.
28. Gravelly clay, 216 ft. to salt.
29. Clay, 25 ft.; sand, 187 ft.; salt at 212 ft.
30. Soil, 3 ft.; sand, 51 1-2 ft.; clay, 3 ft.; sand, 27 1-2 ft.; clay, 6 ft.; salt at 88 ft. (Hazlehurst's Section.) This is the Shaft section.
31 Clay, 17 ft.; sand, 104 ft.; salt at 121 ft.
32. Sand, clay, gravel, 250 ft.; gravel, 75 ft.; sandy, 694 ft.; no salt at 919 ft.
33. Eighty ft. to a gravel bed 22 ft. thick; salt at 102 ft.
34. Clay, 23 ft.; sand and gravel, 100 ft.; salt at 123 ft.
35. Clay, 19 ft.; sand and gravel, 88 ft.; salt at 107 ft.
36. Soil, 1 ft.; sand, 19 ft.; sand and gravel, 77 ft.; salt at 97 ft.
37. Clay, 8 ft.; sand, 42 ft.; sand and gravel, 33 ft.; clay, 17 ft.; sand, 1 ft.; salt at 101 ft.
38 and 39 not known to the writer.
40. Yellow clay, 33 ft.; sand and gravel, 102 ft.; trace of sulphur; blue clay, 3 ft.; salt, 138 ft.
41. Yellow clay, 46 ft.; sand, 99 ft.; rock, 6 ft.; blue clay, 1 ft.; sand, 4 ft.; blue clay, 9 ft.; salt, 165 ft.
42. Yellow clay, 15 ft.; sand and gravel, 94 ft.; blue clay, 3 ft.; salt, 112 ft.
43. Yellow clay, 18 ft.; sand, 90 ft.; clay and gravel, 4 ft.; sand, 10.8 ft.; coarse gravel, 8 ft.; blue clay, 8 ft.; salt, 138.8 ft.
44. Red clay, 45 ft.; sand, 60 ft.; blue clay, 20 ft.; sand, 10 ft.; blue clay, 10 ft.; sand, 1 ft.; salt, 146 ft.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Details of the Mine.—Under history of mining operations we have given the date of the completion of the shaft. Before describing the mining proper, attention must be given for a moment to certain details of the shaft. In this island as well as at Petite Anse and Belle Isle, great difficulty has been experienced in making a water-tight joint at the place where the casing joins with the salt. Leaving aside futile attempts, suffice it to say that here the successful manner of making this joint was as follows: After lowering the iron casing 10 ft. into the salt mass, the cylindric form of the shaft was continued downward for 35 ft. in the manner indicated by Fig. 9. That is, first comes wood lagging, 3 in. thick. Then concrete 1 ft. thick. Then at fairly even intervals, 4 rings of asphalt from 3 to 5 ft. in height, and with bases 2 to 3 ft. thick. Moreover the surface of the salt was heated by hand torches and painted with asphalt everywhere. The heating was carried to such an extent that in some places the liquid asphalt penetrated the salt mass to a depth of 12 inches. So far this joint has shown no signs of leaking.

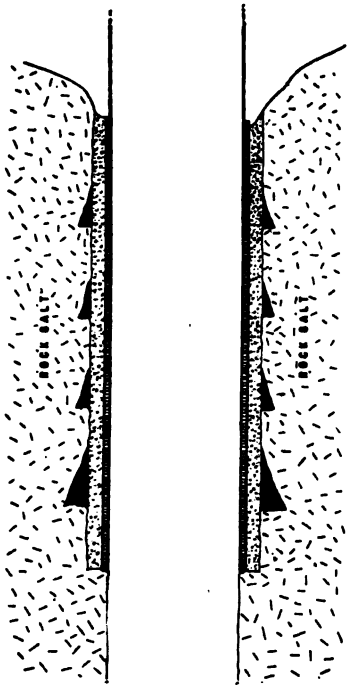

FIG. 9. SHOWING MANNER OF MAKING A WATER-TIGHT JOINT BETWEEN CASING AND SALT, WEEKS, LA.

Below the tubular lagging, i. e. below 135 ft. the shaft is 10 ft. square. The total depth as stated above is 645 ft.

The extent and rate at which mining operations have been carried on here can be gathered at once by examining Fig. 7 and Pl. XVI.

Since 1905 the entries extending northward from the shaft have been connected and the eastward pointing lobes as shown

in Pl. XVI, have been greatly lengthened. To the north of the shaft the salt is more or less impure, to the west there is danger of soon running out of the salt into the overlying sands, hence ruining the mine; to the east the salt is excellent and there appear to be no dangers ahead.

Incidentally it may be noted that hereafter there can be no difficulty in ascertaining the exact position at the surface over any point in the mine. For the writer determined astronomically the azimuth of a line running from the center of the shaft easterly to a point just across the main road to the Sugar House, said point being now marked by an iron post. This line runs east from south 83° 51′. By carefully suspending two plumb bobs as far apart as possible within the shaft and in the line just described, it was found by Mr. Tibbetts and the writer that at the bottom of the shaft, the two plumb bobs indicated a line running more easterly by 2° 2′ than the base line in the main entry. Hence the direction of the main entry is S. 81° 49′ E. Stakes on the surface in front of the office and on the hill beyond were set in such a manner as *to indicate* at the surface the direction of the main entry line. Test wells Nos. 40 and 41 are very nearly on this line.

Mining* is here carried on by first undercutting, or blasting out triangular chunks of salt on the level with the floor of the mine, then blasting down layer after layer, so to speak, already undermined. The drills are worked by compressed air furnished by the compressors in the power house at the surface. The salt is conveyed to the vicinity of the shaft in small dump-cars drawn by mules over narrow-gauge steel tracks. At the shaft the salt is passed through the crusher and falls into a huge bin below.

*Remark.—Doubt often arises as to the size of supporting pillars that should be left in a mine of this kind. To ascertain something as to the crushing strength of this salt, the writer prepared two 4-inch cubes and subjected them each to a pressure of 50,000 pounds, the capacity of the small testing apparatus used, but neither showed any signs of cracking or crushing.

M. Tournaire, Inspector General of Mines, in 1885, tested samples of rock salt from mines close by St. Nicholas and Varangeville, south of Nancy, France, and found that pure rock salt began to crack under pressures ranging from 272 to 394 kg. per square centimeter (3,900 to 5,650 pounds per square inch), and was crushed under pressures ranging from 332 to 461 kg. per square centimeter (4,760 to 6,610 pounds per square inch). Ann des Mines, 1885. Vol. I. p. 358

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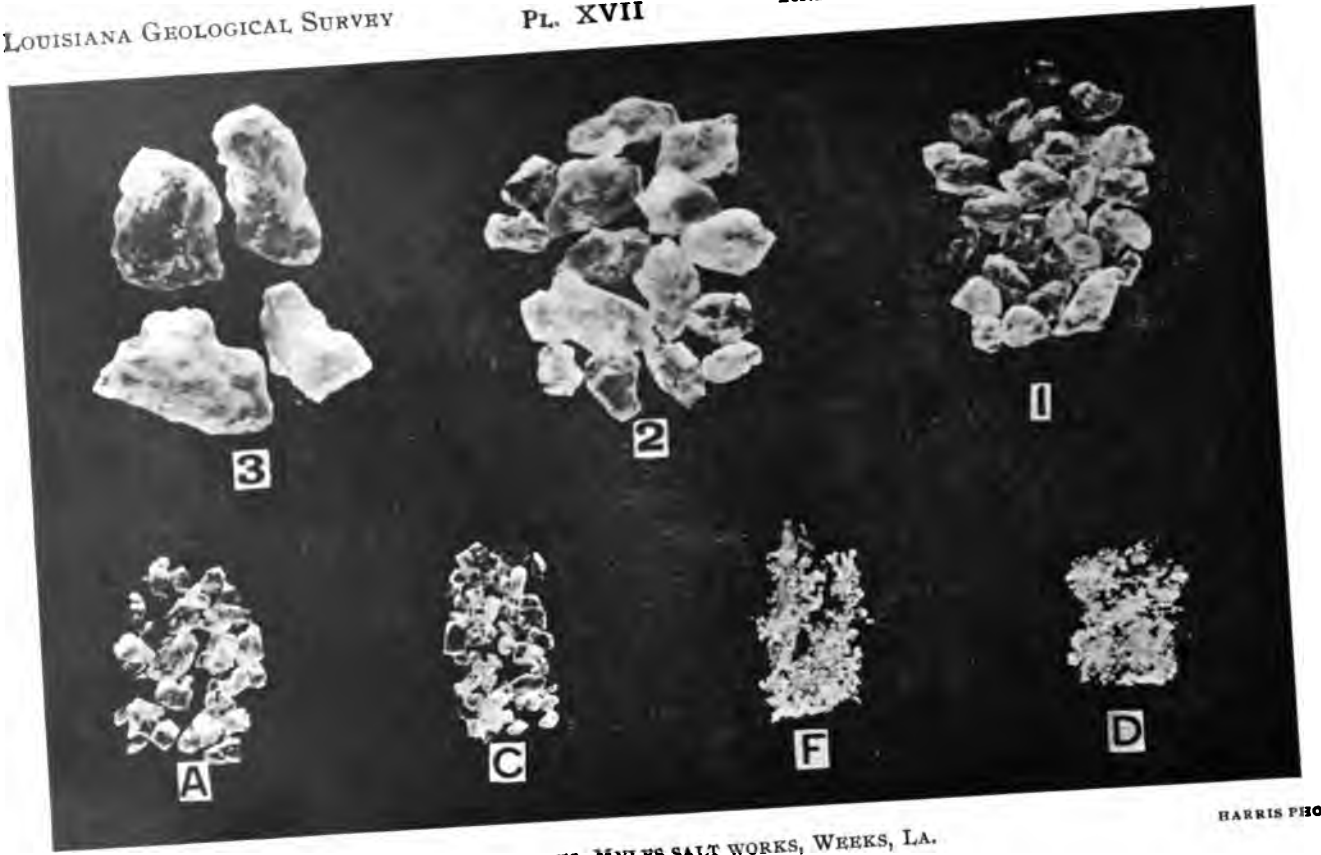


HARRIS PHOTO

SALT SAMPLES, MYLES SALT WORKS, WEEKS, LA.

From this it is drawn off into a five-ton, self-dumping cage, that is capable of making a round trip, i. e. from the bottom of the shaft to the top of the mill at the surface and back to the bottom of the shaft in 4 minutes. The capacity of the mine then is about 75 tons per hour or 750 tons for a 10-hour day.

The mine is lit by electricity. Ventilation is usually fair, but much less satisfactory than it would be if there were provided an entrance and an exit shaft for the air in distant parts of the mine. Fire damp or inflamable gases are practically unknown in this mine.

In the engine room a pair of 20'x30' engines geared back 3½ to 1 turn an 8 ft. drum that winds up the cable lifting the cage. As usual with such machinery, there is a device so actuated by the motion of the engines that the engineer knows at every instant just where in the shaft the cage is, just when to stop the engines to bring the cage to the main floor, to the bottom of the mine or just when he must gradually bring the engines to a standstill while the cage is automatically dumping its cargo in the bins at the top of the mill.

Besides these engines for hoisting, there are two air compressors for working the drills in the mine, one small engine for working the ventilating fans. The power used to run the crusher at the bottom of the shaft as well as the screens and general mill work above is transmitted by insulated wire cables from a dynamo in the engine room. The various boilers shown in Plate XII (behind the salt) use fuel oil.

Kinds of Salt Produced.—Salt of various coarseness is produced at this mill by grinding the crushed materials as it is dumped from the cage, as already described, on the uppermost floor of the building, through screens of varying mesh, the coarser grades being first screened out and the finer ones later on and lower down. Shipment is made *via* the Salt Mine branch of the Southern Pacific Railroad sometimes in bulk in carload lots, sometimes in sacks. The highest priced salt is that shipped in huge chunks, used by cattlemen for salting their stock. In a moderately dry climate these chunks last a year or more, or till consumed by the cattle. Plate XVII shows natural size the grades of salt produced at this mine. The Myles Salt

Company has kindly furnished us the following data regarding the uses to which these various grades of salt are put.

"The crushed salt, grades Nos. 1, 2 and 3, is used for refrigerating, curing hides, curing fish, making salt pickles, glazing in enameling and pipe works, and No. 3 is especially adapted for capping all sorts of meats put up in pickle in barrel.

"The C (coarse) and F (fine) are used for dry-salting meats, clearing oleomargarine and in all sorts of chemical works. The A grade is a special one made to suit the customer who regards the No. 1 as too large and the C as too small for his purposes, such as making ice cream and pickles. The D grade is also a special one, consisting of powdered salt, which results from the grinding of any of the crushed grades in the mills and is used for any purpose where rapid solution of the salt is desired."

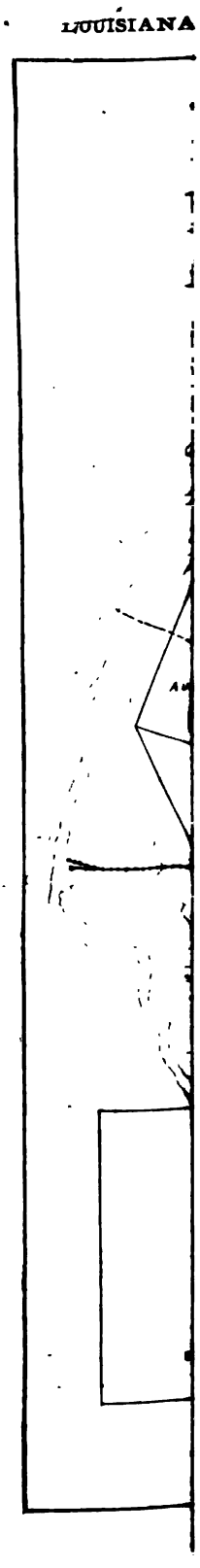
PETITE ANSE—(AVERY'S ISLAND.)

Location, Size and Form.—This island, so-called, is located in Ranges 5 and 6 east, Township 13, south. It is in Iberia Parish about 10 miles southwest of New Iberia. See Pl. XVIII, Bull. No. 3, Report of 1905; see also Map of Petite Anse, Pl. XIX of this report.

History of Mining Operations.—The history of mining operations on this island up to 1899 has been well discussed in a former report of this Survey (Report 1899, pp. 239-243). The main points to be noted are: The discovery of rock salt in 1862, the sinking of an 8x8 ft. shaft 83 ft. deep in 1867, afterwards increased to 90 ft.; the mining by driving long narrow chambers in east-west and finally north-south direction as well; the flooding of the mine; the deepening of the shaft to 168 ft. in 1885, the second flooding, and the commencement of a new shaft in 1899.*

*The most important articles relating to the geology and mining industry of this island are: Report of the American Bureau of Mines on the Rock Salt Deposit of Petite Anse; New York, 1869, by Dr. Charles Goesmann; on the Geology of Lower Louisiana and the Salt Deposit on Petite Anse Island, by E. W. Hilgard, 1871, Smith. Cont. Knowl., No. 248, Vol. 23; R. A. Pomeroy's article on Petite Anse Salt Mine in the Transactions of the American Institute of Mining Engineers (Condensed in Eng. and Min. Jour., Oct. 6, 1886, pp. 280-281); A. F. Lucas's article, The Avery Island Salt Mine and the Joseph Jefferson Salt Deposit, Louisiana, in the Eng. and Min. Jour., Nov. 14, 1896, page 463, and Veatch's article in our own Report of 1899, already referred to.

STUMPY BAYOU. 3 MILES NORTHEAST OF GRAND COTE, LA.
(Showing settling of land; tops of high cypress stumps at sea level; miles distant from cypress trees now living.) HARRIS PHOTO


LOUISIANA

Geology.—The literature already referred to gives a large amount of detailed information regarding the geology of this island. Yet, in our judgment, all these details are of no serious moment in the interpretation of the geology of this and other salt islands. All beds here seen are admittedly of Quaternary age; none contain anything that cannot be referred to inter—or post—Glacial times. Local variations of sediments, tilting of strata that are underlain by salt, submerged cypress stumps about the borders of the island, etc., are points already touched upon under Grande Côte. But since our Report of 1899 was published some most remarkable and unique investigations have been going on that throw much light on the geology of this island and in fact upon the geology of the whole Gulf region. Mr. W. B. Eberhart put down two deep test wells on this island approximately a mile apart. The one he describes as just towards the Mill from the Sugar House, and the other at the present pumping plant.

Section of the well by Sugar House, according to Mr. Eberhart's statement:

	Total depth, feet.
1. Superficial detritus 330 ft.....	330
2. Rock salt, 2,263 ft.....	2,593
3. Blue gas sand, 70 ft.....	2,663
(An old log struck at 2,643.)	
4. Again in salt and ending at.....	2,729

Section of the well at the Pumping Station:

1. Yellowish clay, 500 ft.....	500
2. Gravel, 200 ft.....	700
3. Grayish sand, 2,112 ft.....	2,612
(A gravel bed at about 1,500 ft.)	

No salt nor salt water struck in this well.

In a letter received from Mr. Bradford, manager at the mine, under date of April 27, 1904, the statement is made that at a depth of 1,400 feet in the latter well, logs were passed through; while at about 1,100 ft. a 30 ft. bed of shells was penetrated. He continues: "A mile to the west a well is now down about 800 ft. in hard clay, apparently alluvial deposit, showing hill there to be of much more recent formation than generally be-

lieved. At about same level as underlying surrounding marsh, cypress logs are found. The whole formation is peculiar."

Mr. Eberhart kindly gave us some of the log from 2,643 ft. and we must confess that it seemed much more like wood from a peat bog than from any Tertiary lignite bed. In fact, we believe it to be a part of a cypress tree depressed to this depth in comparatively recent times.

The surface of the salt mass is irregular, as on Grande Côte, but here it rises in places a few feet above tide level, being therefore over 40 ft. higher than at any place on Grande Côte or at any other point in the State. This explains the existence here of brine springs, well known long before the discovery of rock salt on the island.

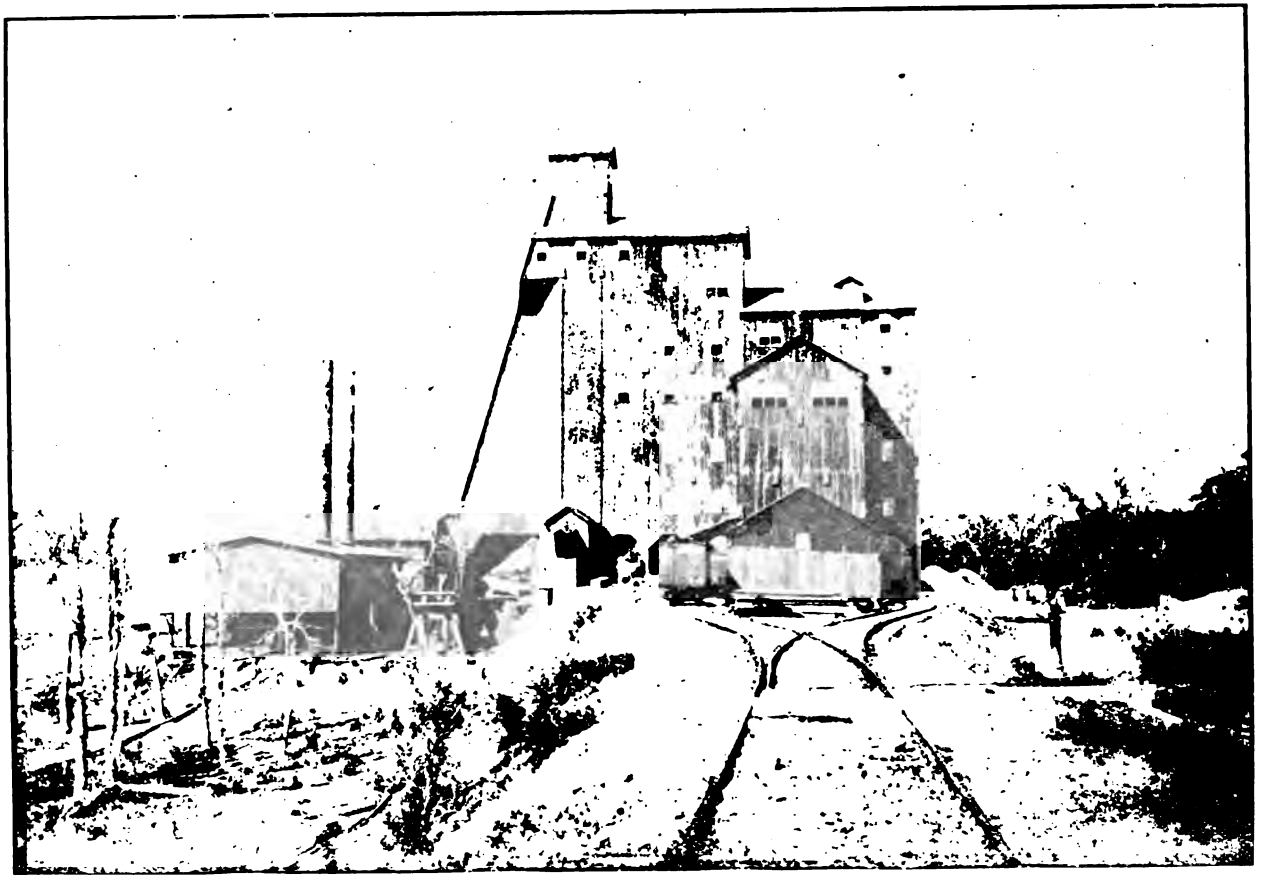
In the mine the salt is streaked nearly vertically as a rule by fine grains of transparent anhydrite crystals as already explained under Grande Côte. An analysis of the white salt placed alongside of an analysis of the dark material is given below (*Fide* Chem. Div. Exp. Sta., J. E. Halligan):

White sample.		*Colored sample.*
99.10	NaCl.	96.53
.10	H_2O	.20
.23	Water insoluble $CaSO_4$	2.16
.33	Water soluble $CaSO_4$	1.05
99.75	Total	99.94

The insoluble calcium sulphate so far as we have observed is transparent, and, we believe that the apparent darkness of the layers bearing it in any quantity is caused by the different way that it and the purer salt layers admit, absorb and refract rays of light. The miners speak of the residue left after everything has been dissolved out that can be in a "colored" specimen, as *white sand.* So it does appear in mass, but when carefully examined under a glass it is seen that the particles are really transparent.

Pomeroy* evidently took these streaks as lines of stratification, for he says: "The stratification planes are clearly denoted and at first sight appear to have been thrown in a vertical position

*Eng. and Min. Jour., 1888, Oct. 6, p. 280.



MILL AT AVERY'S SALT MINE, PETITE ANSE, LA.

SINK HOLES OVER AVERY'S OLD MINE, PETITE ANSE ISLAND, LA.

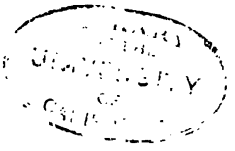
HARRIS PHOTO

INTERIOR OF AVERY'S SALT MINE, PETITE ANSE ISLAND, LA.
(Showing vertical streaks)

Furnished by Avery Salt Co.

HARRIS PHOTO

SALT SAMPLES FROM THE AVERY SALT WORKS, PETITE ANSE ISLAND



throughout; but a close examination reveals the fact that the structure is folded, and shows three anticlinal axes in the first level with the corresponding synclinals in the lower level. In Harper's Magazine for May, 1888, will be seen, p. 909, a cut of a salt quarry at Iletsk, in which the structure is folded."

The two levels it will be remembered were 70 feet apart in the old mine. Since this is abandoned and flooded (See Pl. XXI) we have no means of verifying Pomeroy's observations. The structure he describes seems clearly like that shown in Plate XLVIII, a near view of a portion of the Cordona Salt Mountain.

Details of the Mine.—The shaft is 21x10 ft.; 518 ft. deep; divided into two hoists and one air shaft. Galleries, about a mile of which were already driven in 1904 are 30 ft. wide, and run in two directions, at right angles with each other, leaving square pillars 30 ft. on a side as supports.

Plate XXII shows how that here as well as at Weeks the salt is conveyed from the place of mining to the foot of the shaft by means of small cars drawn on a narrow-gauge track by horse or mule power. Here, however, as at the Retsof mine in New York, the cars are drawn upon the platform of the cage and hoisted and dumped by hand at the top floor of the mill. The heavy crushing is therefore done in the mill instead of at the foot of the shaft, as described at Weeks. The various grades of salt produced here are shown by Plate XXIII and are used for practically the same purposes as similar grades from Weeks. The purity of the salt is such that no purification processes are required. The salt is simply crushed, screened, ground and winnowed to drive off the fine salt dust particles and shipped in sizes shown on Plate XXIII. The elimination of the finest, dust-like particles is necessary owing to their tendency to deliquesce and cement together the larger salt grains.

There is a great similarity in the general type of mill and milling seen here and at the Retsof mines in New York.* This, however, is quite natural owing to the fact that all are in one and the same trust. Owing to the long haul in the Retsof mine, over a mile in some instances, electricity has been installed, however, in place of horse power for moving the salt cars. The Avery salt mill is shown on Plate XX; the Retsof mill on Plate XXXVIII.

Salt, Available and Mined.—Mr. Bradford informed us in 1904 that he estimated the salt deposit actually located to amount to about 2,000,000,000 tons; and that aggregate shipments from this point since time of discovery amount to about 1,000,000 tons.

PART II.—Other localities where salt or cognate substances have been obtained.

LOCALITIES SOUTH OF THE OLIGOCENE.

(See Plate XXIV.)

BELLE ISLE.

Location, Size and Form.—The little mound in the marshes, called Belle Isle, is some distance to the southeast from the other so-called salt islands, being but eight miles to the west of Atchafalaya River. It is reached by boat from Morgan City on the Southern Pacific Railroad. Its exact surroundings, size and form can best be ascertained from an inspection of the maps.

History of Mining Operations.—Salt was found on Belle Isle in December, 1896, by Captain A. F. Lucas, at a depth of 373 ft. (See Report, '99, p. 222.) In August, '98, the Gulf Company started a shaft on the site of their prospect hole No 11, where they had found salt within 103 ft. of the surface. When Veatch, who wrote the article on the Five Islands in our Report of '99 left the island, May 19, '99, the shaft had attained a depth

*The crushing strength of rock salt has already been referred to, p. 10, foot note. One mine mentioned by Tournaire is worked on the very same plan and with practically the same dimensions of galleries as those at Avery's. Leaving one-fourth of the salt area as pillars and allowing 2.2 as the specific gravity of the overlying mass, mining can be carried on, according to Tournaire, on this principle, with safety to a depth of 740 to 1,120 feet, varying with the nature of the salt. See also Ann. des Mines, Vol. 3, 1884, "Des dimensiones a donner aux piliers des carriers."

of 175 ft. and was in impure salt "becoming whiter." After this, an entry was driven first to the north, then easterly 22 ft. wide and 15 ft. high, to a distance of 240 ft., when water rushed in and within two hours filled the shaft to sea level.

A second shaft was started near No. 9, Pl. P, but this seemed to be an unfortunate undertaking from the beginning. Quicksand had to be dealt with for the first 101 ft. Below were 24 feet of sulphur and clay. Then came 75 feet of clay before rock salt could be reached. Attempts were made to freeze the soft materials in order to prevent caving and the inflow of water. The plan could not be carried out. In spite of strenuous work under most abnormal air pressure, the quicksand and water finally rushed in and the shaft had to be abandoned.

On the hill to the north of this shaft the effects of dissolving out salt from a mass overlaid by unconsolidated rock can be seen. An enormous funnel-shaped or crater-like hole in the ground now marks the place whence several thousands of tons of salt were obtained by the common method of pumping brine and evaporating it for salt. By this method that portion of the island underlaid by salt could soon be reduced to sea level and hence ruined.

At the time of the writer's visit to the island, the spring of 1905, everything was dormant so far as mining operations were concerned. The partially constructed boats were rotting at their wharves. The first shaft described by Veatch was marked only by a pond of water. Expensive machinery in evaporating plants and machine shops as well as immense boilers by the score were rapidly rusting into worthless junk. The former postoffice and stores and houses for officers and men were in process of rapid decay.

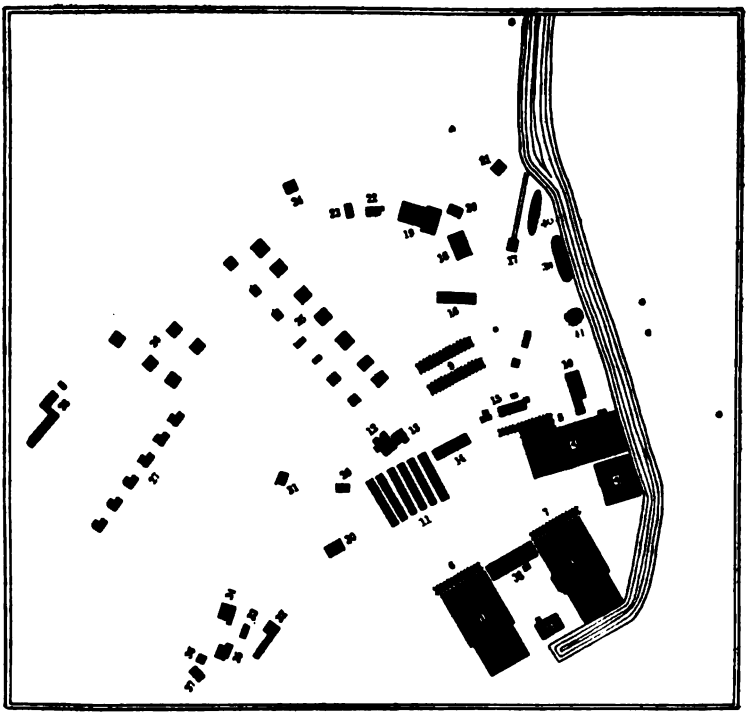


FIG. 10. SALT EVAPORATION PLANT AND ACCESSORY BUILDINGS, BELLE ISLE, LA.

By J. A. Pacheco, La. Geol. Surv.

J. A. Packerd, Louisiana Geological Survey.

1, 3, 5. Evaporation and storage buildings.
2. Drying and packing house.
6-9. Settling tanks.
10. Boiler house.
11. Brick drying shed.
12. Store and postoffice.
13. Brick-making machinery.
14. Barrel factory.
15. Machine and blacksmith shop.
16. Office.
17. Dry dock.
18, 20, 21. Negro laborers' quarters.
19. Boarding house.
22. Oil well.
23-27. Workmen's cottages.
28. Officers' quarters.

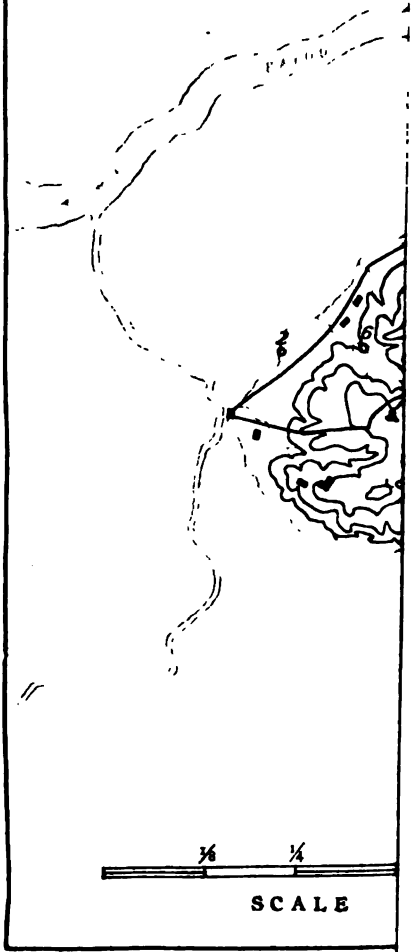
TOPOGRAPHIC MAP

OF

BELLE ISLE

By

A. C. VEATCH



FIG

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18, 2(
19.
22.
23-27.
28.

30. Ovens.
31. Barn.
32. Barn and stalls.
33-35. Saw mill.
36. Second shaft.
37. Electric plant and boilers.
38. Boiler and tall brick chimney.
39. Hull of old "Osceola," used as laborers' quarters.
40. Stern-wheel steamer in process of construction.
41. First shaft; flooded.

Scale approximately 500 ft. to the inch.

A recent letter of inquiry to Mr. C. A. Bibbins at Morgan City elicited the following information: "After the failure of the second shaft all work was abandoned and business was put in the hands of a receiver, who sold all of the plant and buildings. The island is now (Sept. 6, 1907,) in the hands of the New Orleans Milling and Mining Company, who are drilling for oil."

Geology.—The main facts relating to the geology of this island have been well set forth in our Report of '99 by Mr. Veatch. (See pp. 223-229.) Since that report was published, however, ten more wells were put down before our visit in 1905. The samples and drillers' record of several of them were left in the company's office and were turned over to us for study. Unfortunately those left in charge of the island at the time were not acquainted with the location of many of the wells the company had sunk. These ten wells had not been numbered consecutively after the manner of those that had been put down before Veatch's visit, but were given letters of the alphabet, from "A" to "J" inclusive. The logs and samples from some of these furnish interesting and important information.

Section of Well J.

(About ⅛ mi. N. of old shaft on west side of canal.)
Samples at

280 ft., fine, compact, light olive-gray sand.
400 ft., white limestone.
435 ft., crystalline quartz sand and dark clay.
450 ft., light, olive-gray sand, with *Ostrea.*
600 ft., nearly pure quartz sand, rather coarse.

This shows how much less extensive the salt mass is in a northerly direction from the old shaft than it was supposed to be in '99.

Again, by far the most instructive well section from Belle Isle is that from well "I," just beyond the large boarding house from the wharf, not far from the well numbered 1 in Veatch's map. Note that it is only after the 1,545 ft. level is reached that the real salt mass is encountered.

Section of Well I.

Samples at

84 ft., yellow loamy clay.
85 ft., fine sand.
200 ft., coarse sand.
232 ft., coarse angular gravel.
256 ft., coarse angular gravel, with sulphur.
285 ft., sand with sulphur.
303 ft., sand, sulphurous, with traces of oil.
450 ft., fine gray sand.
500 ft., brown sand.
545 ft., sand (gas showing).
565 ft., salt and sand.
590 ft., salt, sand and clay.
608 ft., quicksand, through 2d bed of salt.
655 ft., sand and hard clay.
720 ft., hard clay, "gas" showing.
756 ft., gray sand with pyrites, hard.
785 ft., fine gray sand.
840 ft., salt and hard clay.
852 ft., hard gray shale.
870 ft., hard gray shale. Sulphur.
940 ft., sand and clay, showing oil and gas.
955 ft., hard gray clay.
960 ft., hard brownish-gray clay.
985 ft., brown oil sand mixed with salt.
1,010 ft., dark clay.
1,022 ft., hard black clay and limestone.
1,039 ft., gray clay and sand.
1,040 ft., hard gray clay and gravel.

1,058 ft., dark, hard clay and sand.
1,068 ft., ditto. Casing set at 1,066½ ft. and bailed; bringing up large hard chunks of calcareous gray shale and impure and crystalline gypsum.
1,086 ft., brine, oil, sand, salt, etc.
1,096 ft., olive and brownish clay-shale, sand and salt.
1,105 ft., gray, hard sandy clay, "oil-showing."
1,116 ft., fine brown sandy loam, "good oil showing."
1,130 ft., hard, dark, flaking clay.
1,150 ft., hard gray sandy clay.
1,160 ft., fine, compact sandy shale, salty to taste.*
1,170 ft., brown sand and salt.
1,180 ft., dark hard clay and salt.
1,202 ft., salt and fine sand.
1,206 ft., hard clay, salt and sulphur.
1,212 ft., fine brown sand (oil).
1,220 ft., dark, fine sand (oil).
1,230 ft., ditto.
1,232 ft., "dark shale. Drilled with cable tools."
1,237 ft., dark, hard clay and sand.
1,240 ft., hard clay and oil sand.
1,253 ft., brown sand and hard clay.
This and the above sample appear simply as dark, moist, hard rounded clay nodules.
1,255 ft., ditto.
1,277 ft., ditto.
1,310 ft., ditto, but more sandy.
1,318 ft., ditto.
1,355 ft., light drab, sandy clay.
1,365 ft., light gray, sandy clay. "Fine showing of oil on the return."
1,370 ft., dark, hard clay and sand. "Best oil showing yet."
1,430 ft., hard, light drab to dark, clay sandstone.
1,445 ft., hard, dark gray shale.
1,475 ft., fine, drab, loamy sand.
1,545-2,450 ft., salt.

*Note.—At this depth went through a hard shell and struck a big pressure of gas and good showing of oil.

But a short distance southerly from No. 4 on Veatch's map (Pl. XXV) Well H was sunk. The black stained chert boulders were particularly noticeable in this well, especially from a depth of about 288 ft. Salt of importance was not encountered. This again shows how limited in this direction is the salt mass in which the old shaft was sunk.

Section of Well "H."

Samples from

20 ft., tough black clay.
62 ft., fine, light-gray sand.
104 ft. dark, tenacious clay, with *Ostrea, Modiola* and small univalve as at Anse-la-Butte.
165 ft., fine pure, gray, quartz sand.
220 ft., gray, tenacious clay.
245 ft., very fine gray sand.
266 ft., ditto.
280 ft., ditto, bluish.
288 ft., large chert pebbles and boulders.
315 ditto, black, sulphur-stained.
340 ft., fine sand, with sulphur rock.
363 ft., "Sulphur rock."

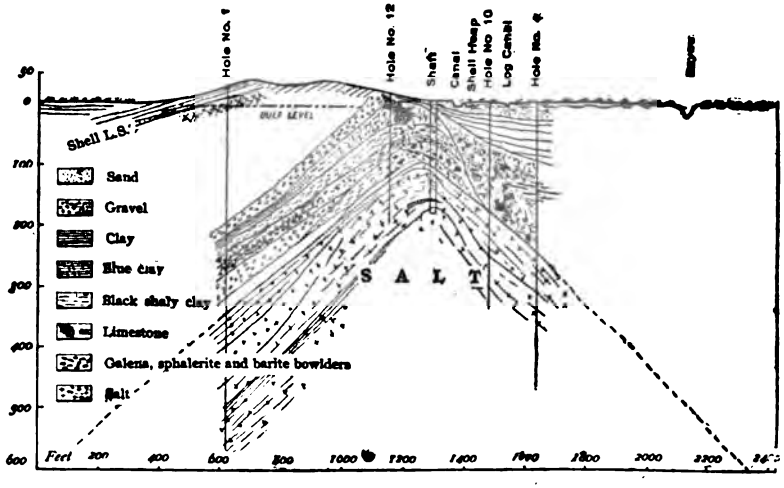

FIG. 11. SECTION ACROSS BELLE ISLE, LA., FROM A TO B; SEE PL. XXV.

370 ft., ditto.
391 ft., ditto.
420 ft., sand, light drab to gray, with clay.

Veatch's cross-section Fig. 11 herewith repeated from Report of '99, though mainly correct, should be so modified as to indicate a very abrupt dipping of the upper surface of the salt to the right of hole 4 or "H." Again if the great mass of salt has been struck at Shaft No. 1, it must have a far steeper dip than shown in Fig. 11, for in Well "I" it is 1,545 feet below the surface.

Well "I" on account both of its depth and the great thickness of salt found is certainly very interesting. But there is another subject of interest in this well; it is the oil found at various horizons, oil by the way of a very light color and so pure that it is burned in lamps without refining.

The shaft section as given by Veatch, though only 175 ft. deep, since it showed the real structure of the beds, i. e. anticlinal, sometimes on one side of the crest and sometimes on the other, deserves special notice. The occurrence of baryte, galena, sphalerite, pyrite, and chalcopyrite are most noteworthy. It runs as follows:

Section of First Shaft.
(Elevation above tide 7 feet.)

No.	Depths.		Feet.	In.
1.	0— 4	Clay	4	0
2.	4— 13	Hard sand	9	0
3.	13— 30	Blue clay	17	0
4.	30— 40	Blue clay and sand	10	0
5.	40— 63	Hard clay and gravel	23	0
6.	63— 68	Blue clay with crystalline masses, from the size of marble to a man's head, of baryte, galena, sphalerite, pyrite and chalcopyrite	5	0
7.	68— 95	Blue clay and shells	27	0
8.	95— 96½	Rock. Impure black limestone and baryte	1	6
9.	96½—103	Blue clay with masses of baryte near the base	6	6
10.	103—116	Dark colored clay with large salt		

	crystals	14	0
11. 116—117	Dark colored clay with oil	1	0
12. 117—142	Salt with dark colored clay	25	0
13. 142—162	Discolored salt	35	0
14. 162—163	White limestone	0	8
15. 163—175	Dirty salt becoming white	12	0

The very recent date of movements in the strata here penetrated is attested by the fact, as pointed out by Veatch, that a shell-bearing layer in the "sand pit" not far away, has a dip conforming with the western slope of the anticline that culminates at the shaft. All shells are of recent species such as live today in the Gulf waters nearby. This accords well with our theory that these salt islands are not largely due to general folding of the earth's crust, but to the concretionary power or perhaps rather to the power of crystallization of local salt masses that presumably are even today increasing in size and causing the doming up of superficial layers.

Salt.—When salt is first struck on this island, it occurs not as pure chloride of sodium as on Côte Carline, Petite Anse or Grande Côte, but as impure, often dark crystalline masses mingled with clay. The deep well "I" shows that if a sufficient depth is reached probably the salt on this island would be very much the same as on the others. But generally the beds nearer the surface have much in common with those found at Anse-la-Butte. Two classes of salt, the light and dark, were obtained by Veatch at the shaft and were analyzed by Dr. Blouin of the Experiment Stations with the following results:

ANALYSES OF SALT.

	Black salt Belle Isle Layer 12 (120 ft.)	White salt Belle Isle (175 ft.)
Sodium chloride	92.750	96.405
Calcium sulphate	——	3.051
Magnesium chloride	——	.074
Magnesium sulphate	——	——
Magnesium carbonate	.201	——
Sodium carbonate	.067	——

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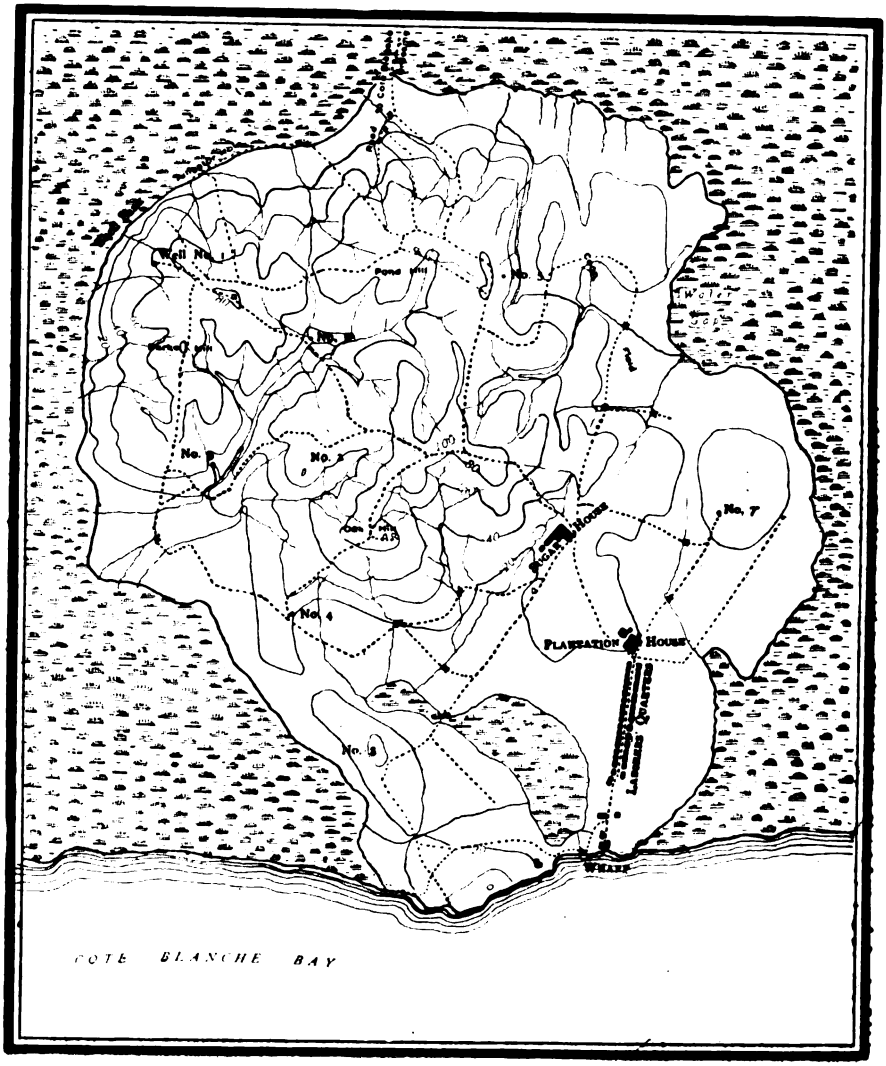


TOPOGRAPHIC MAP OF COTE BLANCHE, LA.
Scale: 2400 ft. to the inch

Sodium sulphate	.837	——
Calcium carbonate	1.804	——
Calcium chloride	——	.226
Ferric and Aluminic Oxides ($Fe_2 O_3$ and $Al_2 O_3$)	.500	.025
Water	——	——
Insoluble matter	3.325	.059

Final Remarks.—We have always looked somewhat askance at Belle Isle as a salt producer. Not but that salt is sufficiently plentiful to supply the whole world's needs for centuries to come, but that the salt is very difficult to obtain in any practical manner. Shafts and mining have proved failures. The beds or lenses of salt nearest the surface are local and dangerous to mine. Dissolving the salt by forcing down fresh water, allowing it to become saturated with salt and then pumping it out again and evaporating the brine to salt is indeed practicable, but, as in England, where the overlying deposits are unconsolidated, the houses, fields and all are ruined by the caving in that takes place soon after any considerable amount of salt is removed. In other words, salt can be obtained in quantities at Belle Isle only by ruining the island.

CÔTE BLANCHE.

General Appearance.—This island has very much the appearance (Pl. XXVI) of Grande Côte, though perhaps it is not quite so rugged. The well sections (Pl. XXVIII) so far obtained, do not differ materially from sections on other islands, except here no salt has been found. Côte Blanche, however, has a long sea-cliff where its stratigraphy can be studied to good advantage. This cliff has been visited and described by Hilgard and Veatch. (See our report for '99, p. 230.) To us, the faults seen here and there along this cliff are its most noteworthy feature. (See Pl. XXVII.) They show that considerable movements have been going on in these beds, movements quite probably due to the salt formation underneath. Here, it would seem is the most advantageous place to bore for salt. Possibly the apex of the salt dome is out at sea now. For, the waves are rapidly undermining this cliff and the whole shore line is and has been for some time undergoing rapid recession. Near the fault shown

in Pl. XXVII the beds exposed from above downwards are as follows:

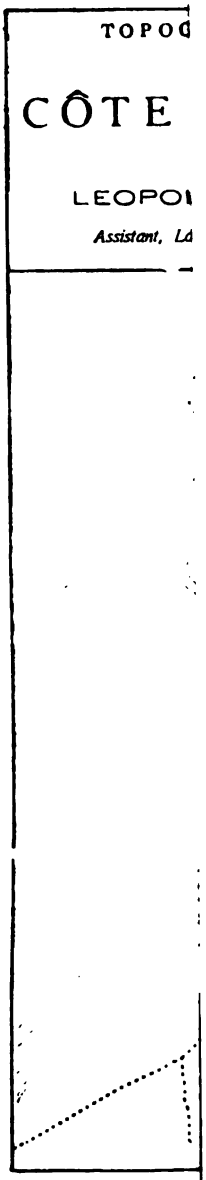
		Feet.
1.	Brownish loam	7
2.	Yellow loam	3
3.	Orange clay	6
4.	Reddish clay	5
5.	Light, sandy clay	2½
6.	Light gray, sandy clay	1½

Final Remarks.—It will be noticed from the sections given on Pl. XXVIII that borings on this "island" have not been very deep, nor have they been in the locality where quite probably the salt core comes nearest the surface. It would seem to us that if a really deep boring, say 2,000 ft., were made on this island and salt were not yet found, that there would be some chance of finding oil in paying quantities. That the uplift or form of the island is due to salt and its attendant materials and phenomena as in the other "salt islands," we do not for a moment doubt.

CÔTE CARLINE.

Location.—On Lake Peigneur, a short distance north of Bob Acres, a station on the Southern Pacific Railroad, about 12 miles west of New Iberia; southwest part of Tp. 12 S., R. 5 E.

Items of Geological Interest.—However questionable the appellation "island" may be to low domes rising out of marshland sometimes nearly dry, sometimes flooded with water, this "island" can only be called such in order to show its similarity of appearance and obviously similar origin to the other members of the Five Island group. The lake bordering this dome is noteworthy in that it is the largest body of water immediately adjacent to or upon any known dome, having an origin we believe connected with that of the dome itself. Note the swamp or lake at Anse-la-Butte, Vinton, the former low depression at Prairie Mamou, Sour Lake, Beaumont oil fields, the lakes on Grande Côte, Petite Anse, Winnfield, Coochie, Belle Isle and others. This island furnished the first well record proving the enormous depth of any salt mass in Louisiana. Rock salt was found at a depth of 334 ft. in a well being sunk in search of fresh water for domestic purposes, in 1895. A diamond drill was then



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employed to investigate the salt mass, and pure salt cores were being brought out when drilling ceased at 2,090 ft. At one place, according to Veatch,* salt is within 91 ft. of the surface. As to exploitations for salt this author says:

Altogether eight holes were drilled to locate the contour of the salt. Only four of these reached the salt. They all show a surface layer of clay from 33 to 110 feet thick beneath which are irregular layers of sand and gravel with one or more layers of blue clay, and in one case a thin layer of lignite. The nearest the salt approaches the surface is 91 feet, in hole No. 8 which showed the following section:

Section of Hole No. 8.

No.	Depths.		Feet.
1.	0— 33	Clay	33
2.	33— 91	Sand and clay	58
3.	91—112	Rock salt, not passed through	21

Blue Clay and Zinc—In hole No. 7, a depth of 442 feet was reached without finding salt. This shows fairly well the usual arrangement of the beds on the island.

Final Remarks.—It is obvious that here salt may be mined at excellent advantage. The small size of the island would suggest the desirability of first thoroughly testing the lay of the salt core before drifting too far in any one direction.

ANSE-LA-BUTTE.

Location.—Northeast of Lafayette, in a direct line 5 miles, by road 5.9 miles; one mile east of Bayou Vermillion, St. Martin Parish. Hypsometrically, the Butte area is from 10 to 29 ft. above the mean level of the Gulf.

Topography.—The cardinal features to be noted here are: 1, a central swamp or lake; 2, a large mound 18 ft. above the lake with major diameter in a northeast-southwest direction; 3, the quadrangular form of the lake, with trend in the same direction as noted in the mound; 4, the less noticeable mounds on either side of the outlet of the lake, and the hint at a similar rise to the east of the lake.

*Report of '99, p. 256.

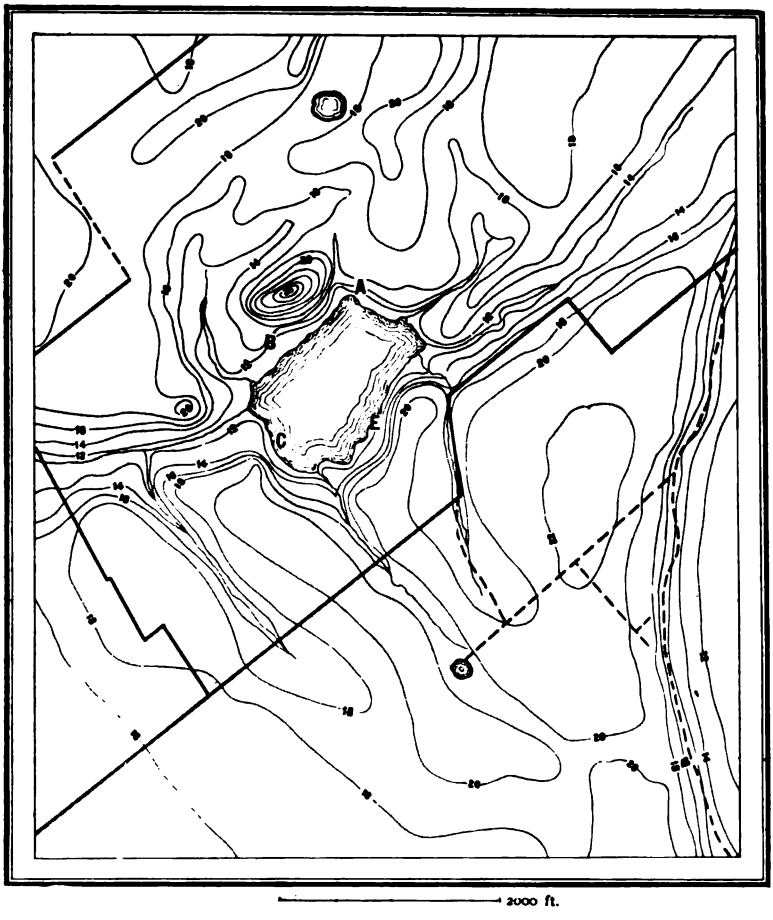
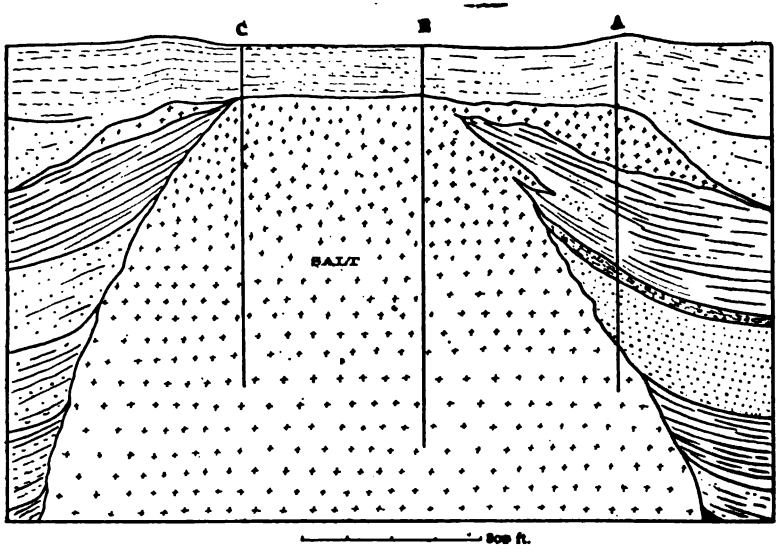


FIG. 12. MAP OF ANSE-LA-BUTTE, LA. SALT LOCATION, A, B, C. BY G. D. HARRIS.

Geology.—This region is usually styled the Anse-la-Butte oil field on account of the location here of a few successful oil wells and the many unsuccessful attempts that have been made to find oil. About 6 out of the 28 wells known to the writer may be regarded as successes in a rather modest way. That there is a great salt mass at this place, dominating the geology of the region is well known. The Martin well (C) on the southern

border of the swamp entered salt at a depth of 245 feet and continued in the same till drilling was discontinued at 1,530 ft. Statements vary as to the amount of salt in the well (B) on the north side of the swamp. Fenneman, however, gives the known salt mass as extending from 220 ft. to the bottom of the well at a depth of 1,803 ft. In one of the first wells sunk, on the very top of the high mound to the north of the swamp, salt is reported as extending from depths 391-570 ft., and again from 578-790 ft., making approximately 400 ft. of salt with 8 ft. of gravel in its midst. In the Heywood No. 1 (A) rock salt was found as we were informed in the field, at 268 and 540 ft. All between these depths Fenneman states to be rock salt. There were clays and sands below, and near the 1,000 ft. mark, considerable quantities of oil were found. The drill again entered rock salt at 1,350 ft. and continued in the same till drilling ceased 200 ft. below. In other wells, only a few hundred feet farther from the center of the swamp, no rock salt has been encountered, though salt water is common from 400 ft. down.



(Horizontal and vertical scale the same.)

FIG. 13. APPROXIMATE CROSS-SECTION OF THE ANSE-LA-BUTTE SALT MASS. FOR POSITION OF WELLS, SEE FIG. 12.

Our interpretation of the occurrence of salt at this locality is indicated in outline by the more or less hypothetical figure herewith given (Fig. 13). Around the salt core, beds of sand, gravel and clay are bent up at an angle of 45° or more; perhaps nearly 90° in some places in juxtaposition with the salt, though in Lake No. 2 doubtless 1,500 ft. or more from the center of the salt mass, a rock layer brought out from a depth of 2,045 ft., according to Mr. Grow, showed a tilting of only about 10°. A sandstone core from the Moresi well showed an inclination of 45°. In all cases, so far as we are aware, the dipping is interpreted by the drillers as away from the center of the field, or swamp.

When a great salt mass is brought up near the surface, fresh waters begin to act upon it. The apex, if not covered by an impervious layer, is soon truncated. About the salt mass there are concentric, truncated cones of pervious as well as impervious layers. Here there are plenty of coarse sand and gravel beds. Saturated salt waters would soon drain off Gulfwards if not in some way checked. Though doubtless checked temporarily by upward flowing oil and gas and made to precipitate small outliers of salt, as shown in Fig. 13, their high specific gravity would at length tell, and as strong brine they would pass downwards, and, commingling with the great well-known water sheets below, would finally leach out into the Gulf. The small quantities of salt precipitated, however, would form ever-increasing masses, and as secondary domes, tend to lift up local areas about the great salt mass. Two such *very modern* uplifts are well shown on the map (Fig. 12). The steepness and the height of the one north of the swamp are sufficient evidence of newness of formation. The one that occurs beneath the outlet is very modern, or now forming; for the outlet valley has marks of extreme youth. It is narrow and comparatively steep. Again this limited area, excepting the notch for the outlet, is higher than the region to the northeast of the swamp. It is very evident that the outlet started its course in this direction when the land to the southwest was the lowest found about the whole periphery of the swamp, and that as time has gone on, and the outlet area has gradually risen, erosion has lowered the channel. Hence now, the comparatively high banks and narrow channel.

Salt Analysis.—In Caracristi's most remarkable report on the Anse-la-Butte (Ledanois) Oil and Mineral Co.'s holdings, p. 14, there is an analysis of brine obtained from a "salt mass," that is interesting in that it not only shows of what the "mass" was composed, but how wonderfully similar its solution appears to the brine obtained in North Louisiana. (See analysis by Maurice Bird of many of the saline waters). The solution or brine contained the following, in percentage to the whole:

Sodium chloride	7.602%
Calcium chloride	0.212%
Magnesium chloride	0.016%
Alumina and iron oxide	0.012%

Final Remarks.—The complete misconception held by Caracristi regarding the geology of this locality can be seen at a glance by consulting his "Cross-section" of the field. The outlying, unimportant masses of salt found in the well on the hill were taken by him as *the* salt masses of the district; and he says: "I find on your properties a deposit of rock salt, covering a workable area of at least five acres, with a thickness of approximately 300 feet." Here then is a case where fact is stranger than fiction, for the drill has already proven a thickness of over 1,200 feet, and a distribution doubtless of 40 acres or more.

Judging from the character of the material in most of these wells, and the fact that over 200 ft. would have to be penetrated to reach the salt, at least so far as we now know, it would seem that shafting would be rather difficult. However, the ordinary process of solution, bringing the salt to the surface in the form of brine, then evaporating the same for salt, would be perfectly feasible, and, if the existence of a lake, finally, where now there is a swamp is not a serious consideration, the method of solution seems the proper one to follow, especially as evaporated salt commands a comparatively high price. The question of fuel is not serious, since oil and gas are on the field.

PRAIRIE MAMOU (JENNINGS OIL FIELD).

Location.—By consulting the large map in Bulletin No. 6, Pl. XI, the exact location and surroundings of this locality can be seen. It is but a mile to the west of the center of T. 9 S., R. 2 W.; about six miles northeast of Jennings in Acadia Parish.

Geology.—Brief mention of this field will suffice here since thus far a rock salt core has not been found. In many ways, however, this seems to us an Anse-la-Butte field, where the salt mass has not been so concentrated laterally, where the dome is consequently much broader, and the depth to the salt much greater. The center of the field is swamp; there is a great mound on the east side of the proven field; the outlet of the swampy district centrally located, shows here also signs of having cut through materials continually rising. We believe that the source of the oil is mainly beyond the limits of the now proven field, and that whereas at Anse-la-Butte oil is found in small pockets about the salt mass where quite often near the surface it has been entrapped, in the Jennings field all lateral sources have contributed to impregnate the sands of the dome. Unlike Anse-la-Butte, here are impervious clay mantles aggregating with their intercalated sands no less than 1,800 ft. The abundance of salt water speaks plainly, though not positively, for the nearby presence of the rock salt mass.

Mention was made in our Report of '02 of the Miocene age of the sands that contain the oil in this field. It was also surmised at that time that here, as at Beaumont, the collection of oil within the limits of a few hundred acres was due to dome structure. As time went on, little was added to what was stated in 1902 regarding the structure of the field. Fenneman's* conclusions were: "There are no determinable dips, if indeed there are any dips at all."

It seems to us, however, that since the abundance and characteristic Miocene *Rangia johnsoni* descends from 1,000 ft. in a Jennings-Heywood Syndicate well near the center of the field, to 2,000 in the Franklin well half a mile east; and since, too, there is a decided mound here, clearly marking deformations in the beds below, to say nothing of the raised overflow channel as above described, there is plenty of evidence of marked orogenic movements and some determinations of dip are possible.

*Bull. 282, U. S. G. S., p. 100.

WELSH.

Location.—About four miles west and a little north of Welsh Station on the S. P. R. R.; Sections 21 and 22; Tp. 9 S., R. 5 W.; Calcasieu Parish.

Geology.—That certain recognizable horizons appear in different wells at different depths, is well established. Hence the conclusion is reached that there have been movements underneath the surface that have produced these known dips. The abundance of salt water is significant, also. So, too, is the localization of gas under tremendous pressure. So far, however, no rock salt has been found. Wells as a rule are about 1,000 feet deep. We have never observed at the surface here any trace of primary or secondary doming.

CHICOT.

Location.—About midway between Oakdale and Ville Platte, eight miles southwest of Bayou Chicot P. O.; S. 35, 3; S., 1 W.; St. Landry Parish.

Topography.—For local topographic features, see Pl. XXX.

Geology.—Two good artificial exposures are seen here. Their relationship, owing to dense vegetation, cannot well be made out. Though nearly pure calcium carbonate, this limestone is often much darker than that at Winnfield. It is often ferruginous, and is replete with cavities, showing affinities with the Winnfield as well as Beaumont limestone. The vertical cutting at the largest quarry shows but eight feet of rock. But from dips obtained at the bottom of the quarry and along the southeast side there can be no doubt that here is a limestone deposit over 30 feet thick; and quite probably it is several hundred feet in thickness. Dips in the quarries show that only the southwestern flank of the anticline or dome is here to be seen. So far no salt, oil nor gas has been discovered here. Yet its apparent concretionary structure, like the Winnfield "Marble" quarry, admits of little doubt. In our Report of '99, pp. 61-62, we noted the prevalent dips to the southwest from 22 to 33 degrees, and called attention to the fact that here the anticline, if such it were, must run in a northwest-southeast direction, while the anticlines then studied farther north ran in a northeast-southwest direction. We see

now from Pl. XXIV that the uplift was probably more influenced by the Five Island fault zone than by the Balcones.

Final Remarks.—This limestone burns into excellent quicklime. Its available mass cannot be ascertained without test wells. But clearly it is much greater than records thus far published would indicate. Here, as at the quarry west of Winnfield, we believe salt might be found by boring. This suggests the manufacturing of soda ash, cement and quicklime. So far, no railroads afford easy access to this place.

SULPHUR.

Location.—About three miles west of Sulphur City; fifteen miles west of Lake Charles, Calcasieu Parish.

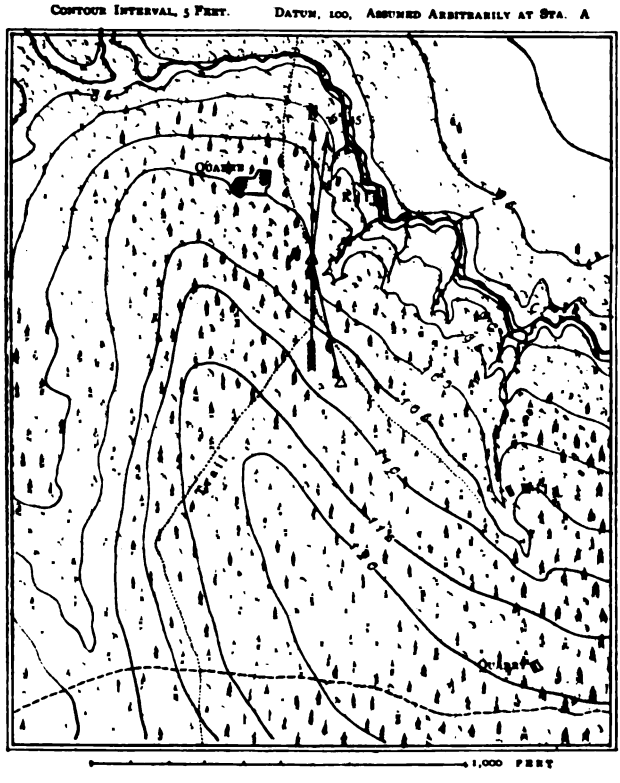
Geology.—This locality is most remarkable for the occurrence between 400 and 600 feet of no less than eight beds of pure sulphur, aggregating 26 feet in thickness. Between these beds sulphur and gypsum occur mixed. For the general features and history of this mine see our Report of '99, p. 126, and Report of '02, pp. 98, 272. So far as we are aware, no rock salt has been reported from this place. The truly dome-shaped structure of the underlying beds is affirmed by Veatch;* as well as by Hayes and Kennedy in 1903.†

VINTON.

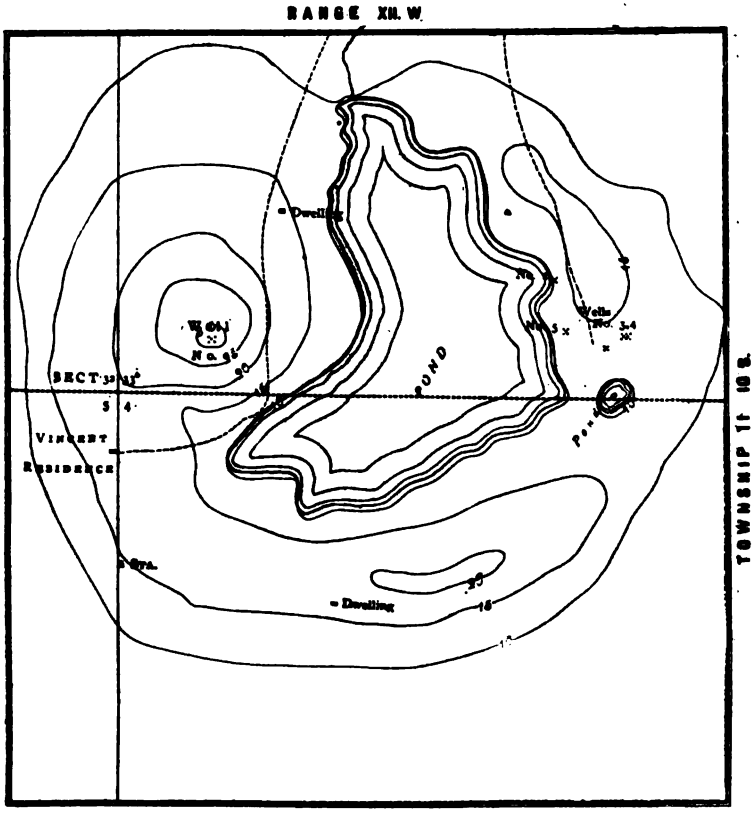
Location.—On sections 33 and 34, 10 S., 12 W., and sections 4 and 5, 11 S. and 12 W.; approximately three miles southwest of Vinton station on the Southern Pacific Railroad; Calcasieu Parish.

Geology.—The general topographic features of this locality are shown in Pl. XXXI. Rising evenly and majestically out of the level prairie region, this dome is certainly an object of beauty, as well as interest, to the scientifically inclined. A little lake we almost expect to find somewhere on or by the side of such domes. *A priori,* one would confidently anticipate finding here not only oil and gas in great quantities, but at no great depth, a tremendous central mass of salt. Here signs fail. However, we have no record of any well on this dome over 1,270 feet deep. Up to this depth, sands and clays, and then

*La. Geol. Surv. Report, 1902, p. 98.
†U. S. G. S. Bull. 212, p. 134.



MAP OF THE VICINITY OF THE CHICOT LIMESTONE OUTCROPS



MAP OF THE VINTON DOME

great thicknesses of coarse gravel are found extending to depths ranging from 475 to 595 feet. Then rock is encountered. Good logs with good samples have not been kept of the wells sunk on this dome, but at the request of the owner, Mr. Vincent, March 17, '04, the driller, Mr. O. W. Myers, of the Vinton Oil and Sulphur Company well No. 2, gave the writer the following log of that well, then down to a depth of 1,016 feet. Since doubt has been expressed* as to the occurrence of solid rock short of 950 feet, this section in detail will doubtless be of some interest:

*U. S. G. S. Bull. No. 282, p. 110, 1906.

	—Feet—	
	From	To
Soil and sand	0	60
Joint clay	60	65
Sand, oil-showing	65	72
Wood, oil-showing	72	75
Sand	75	90
Tough clay	90	101
Sand	101	123
Blue tough clay	123	136
Sand, good showing of oil	136	150
Tough clay	150	165
Oil sand (and gas)	165	172
Tough clay	172	176
Tough clay, oil showing	176	182
Tough clay	182	187
Wood and oil	187	190
Tough clay	190	204
Wood (little oil)	204	206
Sand rock, soft	206	265
Gravel	265	269
Porous sand	269	306
Gravel	306	345
Porous sand	345	360
Gravel	360	375
Rock layer, with gravel	375	381
Gravel	381	387
Rock and gravel	387	396

	Feet	
	From	To
Rock, gravel present	396	403
Hard conglomerate	403	415
Black gravel and sulphur	415	473
Hard rock (white)	473	475
Hard sand rock	475	505
Hard white rock	505	541
Rock with sulphur	541	543
White rock	543	681
Sand rock, water and gas	681	690
Hard rock, white, showing of sulphur	690	755
Very hard rock	755	775
Softer, with showing of sulphur	775	782
Soft sand rock	782	822
Hard sand rock and white rock	822	857
White rock	857	862
White rock	862	875
White rock, hard	875	886
White rock, with sulphur	886	898
Hard rock	898	936
Sand with sulphur	936	940
Soft sand (?) rock	940	1,000
Hard rock (anhydrite)	1,000	1,016

At a depth of 580 feet, there was first noticed an artesian flow of sulphur water and gas.

Brine and sulphur water, gas and oil are found here in small quantities. In our estimation the finding of salt beneath this mound is simply a matter of drilling a 1,500 or 2,000-foot well. The strong flow of artesian water in the heavy beds of gravel above the rock could be used to advantage in dissolving and bringing the salt to the surface. The extensive rock capping of the rock salt would render caving almost impossible.

HACKBERRY.

This locality we have not personally visited, but from descriptions and well sections given in Bulletins 212 and 282 of the United States Geological Survey it is evident that here is

a structure of lower, broader and less definite dome characters than obtain at Vinton. Its location is given as 33 miles southwest of Lake Charles, on the south bank of Black Bayou, between Black Lake and Calcasieu Lake. Its area is said to be 8,000 acres and its elevation 35 feet. Sands, clays and gravels extend to a depth of about 900 feet. Only thin layers of hard rock occur till a depth of 1,565 feet is attained. Then comes a 45-foot bed of porous limestone. At 1,620 gypsum occurs and continues at least to 1,830, the bottom of the deepest well. From a fine black sand between these rock formations salt water was reported.

DAVIS HILL.

Location.—Northern part of Liberty County, Texas; on the right bank of the Trinity River.

Regarding this hill Kennedy and Hayes* say:

"This is an elevation located about 20 miles north of Dayton. Considerable quantities of sulphur water and inflammable gas are reported as occurring, but no prospecting or drilling has yet been done. The surface formations of this locality are mostly sands and soft sandstones."

Hager maps this as a *mound* locality in Eng. and Min. Jour.

SARATOGA.

Location.—West central Hardin County; twelve miles north and a little west of Sour Lake.

This is a small oil field that shows no dome structure at the surface; nor are there any conclusive proofs of anti-clinal structure beneath, except, of course, the peculiar confinement of the oil to perhaps not over 200 acres of surface. Deep wells, 1,400-1,700 feet, in the northern part of the field yield salt water in great abundance. In many ways the descriptions† of this field recall conditions at Prairie Mamou.

Fenneman notes the lack at the surface of all traces of a hill or mound indicating the usual structure of these fields. Still, mention is made of a somewhat significant fact—that the longest dimension of the field "has a trend a little east of north." *Op. cit.*, p. 62.)

*U. S. G. S., Bull. 282, p. 62.

BATSON.

Location.—One mile from Batson P. O., Hardin County, seven miles southwest of Saratoga; thirteen miles northwest of Sour Lake.

Geology.—In this field, oil is found in a porous limestone averaging from 1,100 to 1,200 feet beneath the surface and having a thickness of from 20 to 30 feet. This limestone affords the means for determining some structural features in the low-lying beds of the region. Fenneman* mentions the strong dip in the eastern part of the field to the northeast, but also mentions a crest passing northeasterly through the same area implying a pitching crest. Whether these features have been correctly made out or no, it is certainly noteworthy that, if our supposition that this field is underlain by two faults or folds nearly at right angles to each other, the probable result of the upheaving forces along these lines would be precisely what has been described.

"There is but one mention of the occurrence of salt at Batson. If the observations of the drillers were correct, 12 feet of salt were found in the Paraffine No. 12, northeast of the centre of the field, at a depth of 1,007 feet, or 130 feet above the oil rock." (*Op. cit.*, p. 53.)

BIG HILL.

Certain marked elevations in three different countries have received the commonplace designation, "Big Hill."

Big Hill in east Liberty County we know only from Hager's map.

Big Hill in Jefferson County must bear considerable resemblance to the Vinton mound, in that it is low and broad and, though possessing calcareous beds in abundance and seemingly of the proper nature, they fail to yield much oil. One well is reported as reaching calcareous rock at 350 feet and continuing in the same to 1,400 feet, the total depth of the well. Another found none of the dome materials till a depth of 2,496 feet was attained, where limestone, gypsum and pyrite were struck. This was drilled into 34 feet and the well abandoned.†

*U. S. G. S. Bull. 282, p 52.
†U. S. G. S. Bull. 282, p. 79.

Big Hill, Matagorda County, is interesting from the fact that it has yielded a sufficient amount of oil to encourage the sinking of perhaps forty wells, furnishing sufficient data to prove the symmetrical dome structure of the oil-bearing porous limestone. The dome at the surface is 20 feet high; but the dome of the limestone is 200 or more feet high, with heavy dips about its periphery. Oil and gas comes in largest quantity from near the center of the mound. Salt water was found in nearly every well and has increased enormously in proportion to the amount of oil.

SOUR LAKE.

Location.—Southwestern part of Hardin County; twenty miles northwest of Beaumont.

Geology.—Here is an instance where erosion and doubtless solution have been carried on to a sufficient extent to obliterate all noticeable traces of mound or dome structure at the surface. But in no other case is there such positive proof of marked orogenic movement as here. Besides the northeasterly, steeply-dipping porous limestone ledge described by Fenneman* in the Wirt Davis tract, clearly showing a dip in some instances of 45%, we have here the positive proof of Jackson Eocene fossils from a depth of 1,075 feet or less. Other deeper wells, especially the "wild-cat" well four miles to the southeast of Sour Lake, showed recent species, though some of the material had lithologic resemblances to the Flemming clays. Suppose the dip between the two is 60 feet per mile Gulfward, and suppose the Flemming clays were completely penetrated in the southeast well; this would mean that the top of the Grand Gulf beds should appear in the Sour Lake well at 1,675 feet. Veatch makes the thickness of the Grand Gulf (Catahoula) beds 1,100 feet. The top of the Jackson beds should then be reached at Sour Lake at 2,775 feet. But the Jackson beds *are* reached (and perhaps not their topmost layers either) at a depth of less than 1,100 feet! Here then is positive proof of a dome-like or local uplift of fully a thousand feet and quite probably much more. In spite of these telling facts regarding the substructure of this locality, they have

*U. S. G. S. Bull. No. 282, p. 42.

been entirely overlooked by recent writers on the geology of this region. In our way of thinking, the steep N. E. dips recorded in the porous, oil-bearing limestone in the Wirt Davis tract are to be referred to a Batson-Spindle Top anticline or fault, and the S. E. dips of the Cannon tract to the influence of a faulting at approximately right angles to the first or nearly parallel to the coast. Between these tracts the Jackson Eocene is shown to come within 1,100 feet of the surface. That the edges of Jackson beds should be so turned up that they break through 1,000 feet of Grand Gulf beds is no more strange than the breaking through and coming to the surface of Cretaceous beds about the "Salines" of north Louisiana and east Texas. The great importance of the finding of Jackson fossils here is that in no other place south of the Grand Gulf area do we know positively that Eocene beds have been reached in wells. Here we have a strong hint as to the deep-seated nature of the cause of the domes of the Gulf border region. It tallies nicely with facts gained in studying similar structures in north Louisiana.

Salt is reported by Fenneman as being found in at least ten of the wells of the Wirt Davis tract (and the adjoining) at depths apparently from 800 feet to 1,000 feet or more. It is beneath the porous oil-bearing limestone, separated from the same by hard clay.

SPINDLE TOP.

Location.—Jefferson County; a little east of south from Beaumont, about three miles.

Geology.—This is perhaps the most widely known of all the oil fields along the Gulf border. Here it was that in January, 1901, Capt. Lucas brought in the first gusher and opened the eyes of the commercial world to the oil possibilities of the Southern States. Bulletins 212 and 282 discuss this field at length with maps and various illustrations. The propriety of the name Spindle Top is indeed questionable, for the mound as named is but about 10 feet high with an area of perhaps 200 acres. In the map published in Bulletin 212 there seems to be no marked elongation of the mound, though perhaps there is a slight tendency to extend a little further in a northwest-

southeast direction than in any other way. The proven area would seem to have a major axis in a northeast-southwest direction. The oil rock, a porous limestone, shows a doming of at least 200 feet. It is encountered at depths of from about 775 feet to 1,080 feet. The occurrence* of rock salt is known from the logs of at least two wells, the Iowa-Beaumont and the Higgins No. 3. In the former it was met at 1,200 feet and continued till drilling ceased at 1,790 feet. In the latter, salt was met at 1,647 feet and still continued at 1,990 feet. Rock salt is reported in one instance at 600 feet with a thickness of 10 feet.

DAYTON.

Location.—Southwest central Liberty County; eight miles west-northwest of the village at Dayton.

Geology.—The locality here under consideration, usually called Dayton Hill, is not a well-defined dome, but rather ill-defined, perhaps 20 or 30 feet above the surrounding country and 6 miles across. In one sense of the word it is a complete Gulf Coast dome, for it contains at successive horizons limestone, gypsum, and in some places oil and gas, and finally below, with unknown thickness, rock salt. As an example, the Taylor-Dayton No. 1 passed through the usual unconsolidated sands and clays to a depth of 580 feet. The sands contained some oil. Then came a 10-foot limestone with soil showings. From 590 to 799 feet, solid gypsum was found. Then came 500 feet of solid rock salt. Other wells have reached the salt mass, especially in the western part of the field.†

HUMBLE.

Location.—Eighteen miles north of Houston, northern Harris County.

There is an oil field covering a part of Echols Ridge. Oil is found, sometimes at least, in the usual porous limestone of these districts. Depth about 1,200 feet. No salt reported, but salt water has flooded the wells.‡

*U. S. G. S. Bull. No. 282, p. 31.
†U. S. G. S. Bull. No. 282, p. 85.
‡See U. S. G. S. Bull. No. 282, pp. 67-68.

BARBER'S HILL.

Location.—Northwestern Chambers County; eighteen miles south of Dayton.

From Fenneman's* description of this mound we judge it must be very similar to that at Vinton, La. It is 20 feet high and covers several thousand of acres. One well at least out of the five drilled by Higgins showed from 557 feet down to 1,200 feet gypsum in what were supposed to be large concretionary masses, not one thick layer; nor was rock salt struck.

HIGH ISLAND.

Location.—In the southeastern part of Chambers County. For local surroundings see Fig. 14.

Judging from well records and statements of Hager and Fenneman, gypsum is commonly found at shallow depths intercalated in clays. One of the Guffey wells found gypsum at 600 and stopped in the same substance at 1,200 feet. Another Guffey well penetrated gypsum from 900 to 1,300 feet and then went through solid rock salt to 2,600 feet. Hot waters and various sulphur compounds, resembling those at Belle Isle, are noticeable.

BLUE RIDGE.

The location and facts regarding this locality we owe to Hager.† He says: At Blue Ridge, in Fort Bend County, a well now being sunk passed through a heavy series of coarse sands and gravels, from 200 to 600 feet, cemented together into a hard conglomerate by a matrix of gypsum and dolomitic material. Pockets and seams of slate occur throughout this conglomerate intimately mingled with gypsum, dolomite and gravel. Pyrite and large crystals of sulphur are found in abundance in the same material, with evidence of gas and petroleum.

HOSKIN'S MOUND.

Location.—Southeastern part of Brazoria County; between Chocolate and Bastrop bayous.

Fenneman states this mound has a height of 37 feet above the Gulf and about 30 feet above the level of the surrounding land. A few comparatively shallow wells are reported to find oil, and

*U. S. G. S. Bull No. 282, p. 83.
†Eng. Min. Jour., July 28, '04, pp. 138-139.

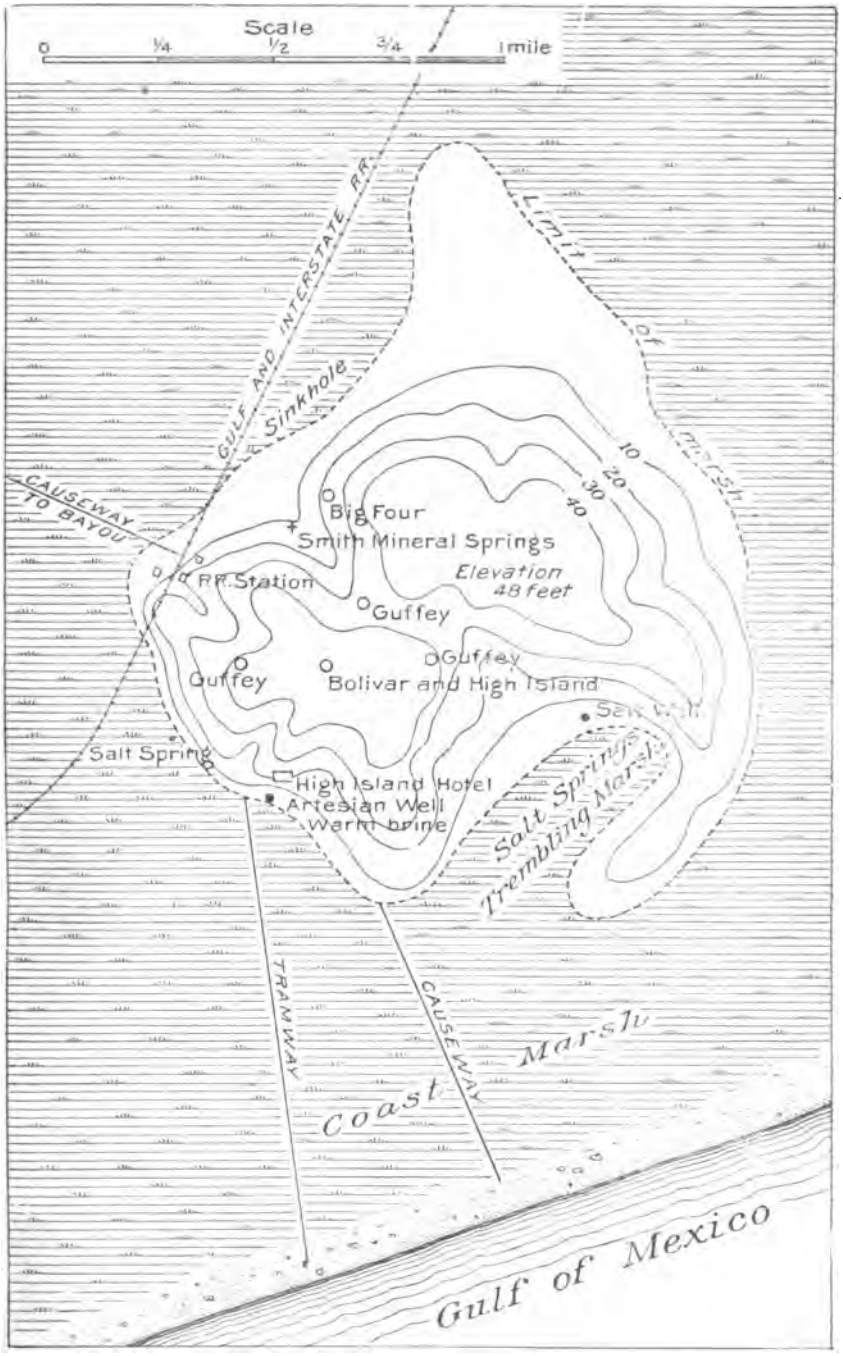


FIG. 14. HIGH ISLAND, CHAMBERS CO., TEX.—FROM U. S. G. S.

it would seem that some of the typical dome materials are present, but as yet no rock salt has been reported.

DAMON'S MOUND.

Location.—In the northwestern corner of Brazoria County.

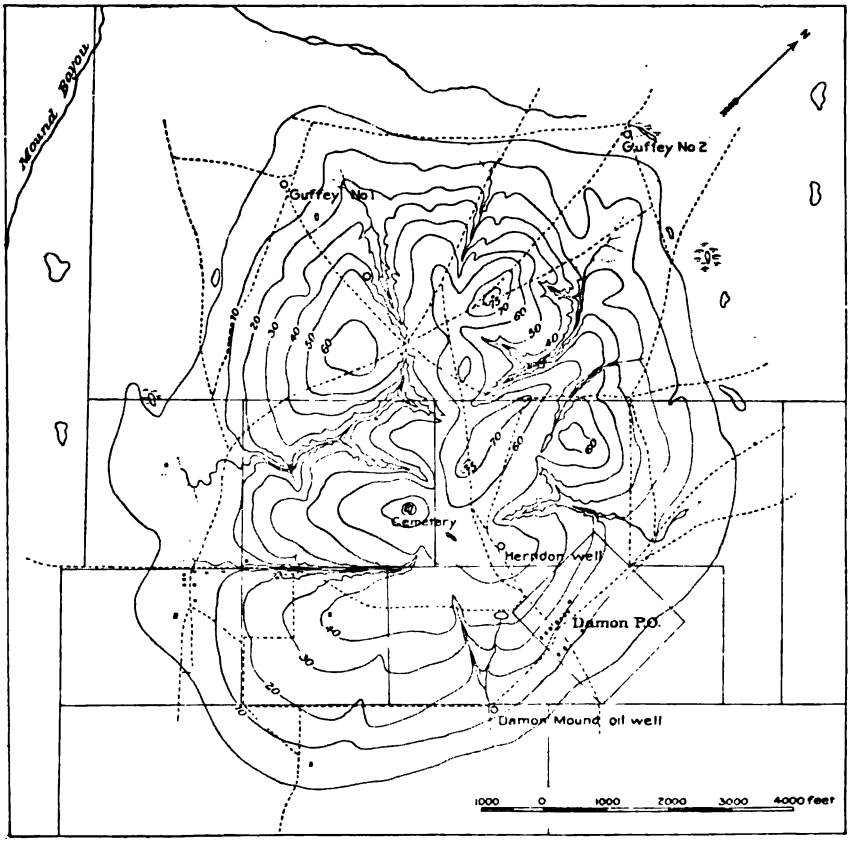


FIG. 15. SKETCH MAP OF DAMON'S MOUND, TEXAS, BY VEATCH, U. S. G. S.

Geology.—The general topographic features are well shown on the map made by Veatch for Bull. No 212 of the U. S. G. S.

In the Herndon well Hayes and Kennedy note:

	Feet
Gypsum	171 to 549
Sulphur and gypsum	549 to 579
Loose sand, very coarse	579 to 587
Salt	587 to 1,160

KISER'S HILL.

Location.—Brazoria County; near west bank of the Brazos; two miles northwest of Columbia.

This is described by Fenneman as an irregular elevation of 30 feet above the surrounding plain. Thus far it seems not a successful oil field. Some wells have reached a depth of over 1,000 feet. Some oil, gas, sulphur, and even streaks of salt have been found.

BRYANT'S HEIGHTS.

Location.—Brazoria County, one mile from the Gulf and not far west of the mouth of Brazos River.

This mound rises about 30 feet above tide, or about 20 feet above the surrounding plain. According to Fenneman's description it would appear to be similar to Kiser's Hill. Sulphur and gypsum are mentioned, but, so far, no salt.

LOCALITIES NORTH OF THE OLIGOCENE.

(See Plate XXIV.)

NEGREET SALINE.

Location.—About one-half miles above the mouth of Bayou Negreet, in the S. W. ¼, S. 24, T. 5 N., R. 13 W.

General Features and Importance.—Brine springs issue from the bed of the bayou; and, formerly vertical hollow logs were sunk over these sources and the brine pumped to kettles near by and evaporated. In this vicinity there are no extensive level, barren tracts as near some of the larger licks in northern Louisiana, yet the stunted growth of the vegetation scattered about among barren sandy patches of ground show clearly a true saline, indicating doubtless the near approach to the surface of a considerable mass of rock salt.

COAL BLUFF SALINE.

Location.—On the Sabine River, S. 33, T. 6 N., R. 13 W.

A small open lick showing a few old furnaces and of an importance equal to the Negreet saline.

Still further north and west in S. 2, 6 N., 14 W., another small treeless "lick" is reported, where salt was made in early times.

MANY.

Location.—On the road from Marthaville to Many, near Rock Spring Church (N. E. ¼, S. 24, 8 N., 11 W.).

A dome structure is inferred here on account of the Midway aspect of the fossils occurring in an impure limestone ledge surrounded by Sabine Eocene deposits. See Report of '99, p. 63.

BAYOU CASTOR SALINE.

Location.—About five miles in a northerly direction from Rochelle; about on the line between sections 15 and 22, 10 N., 1 E. (*fide* Smythe of Rochelle), the so-called "dry lake" being probably all in S. 15.

This is probably the region referred to by Kilpatrick in 1852 as "on the west bank of Castor Bayou four miles from the fork," quoted in our Report of 1902, p. 92. If so, the Castor Salt Spring, given on the maps of Professional Paper No. 46 is about six miles too far north.

Size and Form.—The various licks cover a space we estimated as having a length, east and west, of about 4,000 feet and a breadth, north and south, of 1,000 feet.

Geology.—The various "licks" are here small in comparison with those at Cedar or Drake's saline. Still, that there are large salt masses not far below the surface in this region no one can doubt. From a casual look at the district, it appears that there is a rise of ground in the center, somewhat after the manner of "Lick Hill" at Price's saline. To the south of the log-tram that traverses this saline the hills are seen to rise very abruptly out of the semi-barren lick plains. Some forces besides mere erosion have been at work forming this topography.

Half way back to Rochelle along the tram just mentioned, other small "licks" are seen. Vegetation is prevented from growing over patches several yards square by the licking of the ground by cattle that range in the woods.

BROWN'S SALINE.

Location.—By wagon road six miles westerly from Tullos, or eighteen miles southeasterly from Winnfield, on the north bank of the Dugdemona. Time has not yet permitted us to visit and map this saline.

Size and Importance.—Described as not so extensive as Cedar Bayou Saline, yet as having furnished much salt "before the war." This seems to be the locality referred to below by Smythe as SS. 14, 23 and 24, 10 N., 1 W.

SALT WELLS ABOUT GEORGETOWN.

At Rochelle.—Mr. Smythe, surveyor to the Louisiana Lumber Company gives the following notes relative to a deep well sunk at Rochelle with the hope of finding an abundant supply of potable water. Depth of well, 1,780 feet; water brackish at 700 feet, becoming very salty below; limestone layer 4 feet thick penetrated between 250 and 300 feet; fairly good fresh water veins met with between 400 and 600 feet, water rising to within 10 feet of the surface; limestone 40 feet thick betweeen 600 and 700 feet; sandstone layer 5 feet thick at about 1,300; clay to hard rock at 1,780, where well was abandoned.

At Tullos.—A well furnished brackish water at 300 feet; very salty at 960.

At Georgetown.—One hundred and fifty yards east of the I. M. and L. and A. R. R. junction and about 20 feet north of the L. and A. track.

Well showed salt water at 480 feet, and casing was set on hard substance, supposed to be rock salt, at 510 feet.

At Selma.—Mr. V. M. Mason, superintendent Grant Land and Lumber Company, says a well was sunk by the mills to a depth of 400 feet. The first 57 feet were sandy; a sandstone ledge was met with at 350. At 400 feet salt water appeared; salt water rising from 12 to 14 inches above the general surface of the ground. This brine when boiled down gives 3% chloride of sodium.

At Cedar Bayou Saline.—(See Bull. No. 5, La. Geol. Surv.)

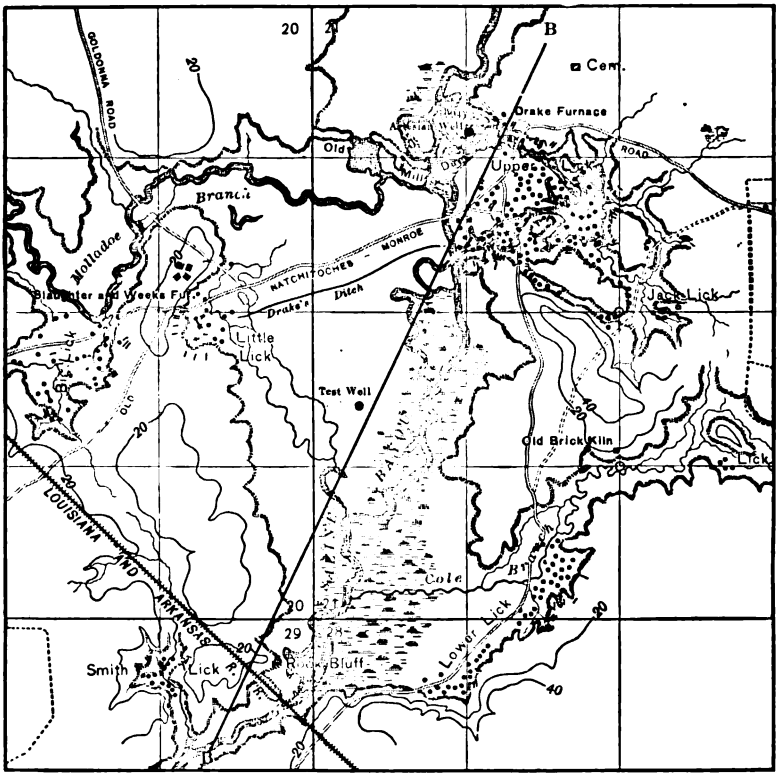
At Winnfield Dome.—(See Bull. 5. La. Geol. Surv.)

At Coochie Dome.—(See Bull. 5. La. Geol. Surv.)

DRAKE'S SALINE.

Location.—About the middle of Township 12 N., Range 5 W., on Saline Bayou.

Size.—Second only to Bistineau. See Fig. 16.



DRAKE'S SALT WORKS, WINN-NATCHITOCHES PARISH, LA.

1899.

MAPS SHOWING CHARACTERISTIC, SYMMETRICAL, CIRCULAR ARRANGEMENT OF SHALLOW BRINE WELLS AROUND THE TRUNCATED DOMES OF NORTHERN LOUISIANA.

BY A. C. VEATCH

Scale

0 ¼ ½ ¾ 1 mile

FIG. 16.

Geology.—There are several "licks" that go to make up Drake's saline or salt works. They are level, barren patches arranged roughly in a circular form, and surrounded exteriorly

by low hills or knolls, as described under Cedar saline. No outcrops are to be seen in the immediate vicinity of the licks that carry fossil remains, though from the many small prairies but a few miles distant it is to be presumed that the hill land in the immediate vicinity of the licks is all referable to the Lower Claiborne sub-stage. At Rock Bluff, as indicated in Fig. 16 there is a bluff of steeply dipping calcareous sandstone of the general appearance of that at Coochie Brake.

The position of the "artesian well" frequently spoken of in connection with this saline is shown in Fig. 16. Regarding the same Veatch remarks (La. G. S. '02, p. 60): "The artesian well is said to have passed through solid limestone for its whole depth, 1,011 feet, and Hilgard reports that a few of the fragments taken from the hole which were to be seen at the time of his visit were almost identical with the 'rotten limestone' of Alabama and Mississippi, or Upper Cretaceous. The brine from this well has a temperature of 75° F. and the gas which escapes with it will support a flame half an inch in diameter and six inches high."

Serious doubts have been felt as to the real depth of this so-called deep artesian well. It seems to us a temperature of 90° F. would be more in accordance with what would be expected from waters coming from any such depth. Again, the extreme weakness of the brine is scarcely in accord with the great depth given. The mechanical difficulties that would arise in sinking a well 1,000 feet or more "in the early forties," long before the requirements of the oil fields of this country had called into existence modern drilling outfits, would have certainly been many and serious.

Recently a test well has been sunk at the place indicated in Fig. 16 and a partial log has been published as follows (Veatch, Prof. Pap. 46, U. S. G. S., p. 300):

Partial section of test well at Drake's Salt Works, Sec. 21, T. 12 N., R. 5 W., Natchitoches Parish, La.:

	—Feet.—
1. Yellow sand clay	0 to 5
2. White sand, with water which steams all right in a boiler, but turns deep red and coats everything with a salty crust	5 to 42
3. Cypress log, very much decayed, charred on one side	42 to 43
4. Soft sand, gravel and streaks of clay of various colors so mixed in drilling that we could not classify or give stratification	43 to 318
5. Very porous crystalline limestone; crevices filled with white and yellow calcite crystals	318 to 475

"At 150 feet a foam found on the water which tasted very much of alum, puckering the mouth very much."

Samples from stratum 5 are in every way identical with the limestone found at the Winnfield "Marble Quarry."

According to the driller in charge of the well March 24, '06, the time of the writer's visit, the log of the completed well may be stated in outline thus:

	—Feet.—
Soil, muck, pebbles, logs	0 to 303
Limestone (like Winnfield marble)	303 to 910
Salt	910 to 2,320
Gypsum bed at bottom	2,342

Under date of August 17, '07, Mr. J. H. Brewton, P. M., informs us: "They have put down another well one-half mile north of the first one and have found quite a lot of gas and some oil, but no salt."

Considering the recent developments in this field we would suggest the modification of Veatch's cross-section as given on p. 61, La. Surv. '02, into that given herewith, Fig. 17. Not only is this figure more in accord with the facts as known at present, but also here is a way of explaining the occurrence of salt licks arranged in a general circular outline.

Note.—No enormous dislocation is postulated.

Production.—Although salt is not being produced at this locality now, the number of furnaces that were once running

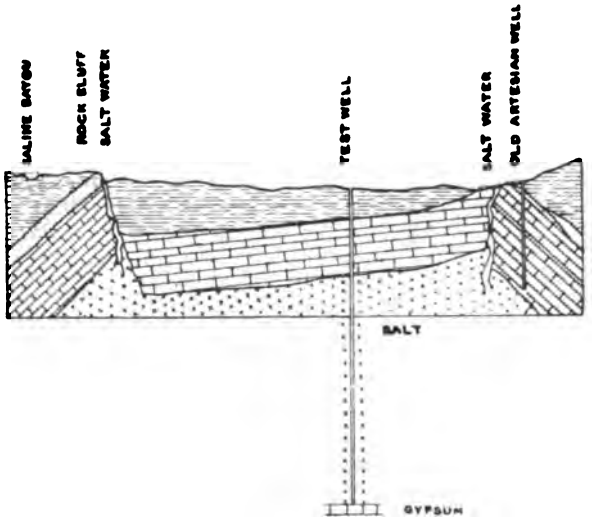


FIG. 17. HYPOTHETICAL CROSS-SECTION OF DRAKE'S SALINE, GOLDONNA, LA.

(Test well is 2,742 feet deep.)

especially in war times, indicate its importance in times gone by. For details and history of these works, see La. Geol. Surv., Rep't '02, pp. 51-64.

Analyses of brines are quoted below from pp. 63-64 of our Report of '02.

Analyses of brines from Drake's Salt Works, Winn Parish, La.

(By Maurice Bird.)

Constituents (in parts per hundred).	I.	II.	III.	IV.
Sodium chloride	4.90	3.55	5.58	5.44
Calcium chloride	.184	.127	.303	3.56
Magnesium chloride	.142	.133	.135	.159
Alumina	.061	.066	.072	.055
Other solid matter	.083	.044	.070	.030

I. Little lick, west side, old Drake lick.
II. Smith's lick.
III. Lower lick, old Drake well.
IV. Upper lick, south side, in slough.

PRICE'S SALINE.

Location.—Six miles northeast of Drake's, SS. 25 and 30, 13 N., 4 and 5 W., near the edge of Dugdemona bottoms.

Size.—See Plate XXXII.

Geology.—But one small rock outcrop is known here, showing indurated material very much like that described at Drake's and Coochie brake. The presence of a dome-shaped hill between the various licks is, so far as North Louisiana is concerned, rather remarkable. Salt could doubtless be found at no great depth in the center of this hill.

Production.—This never was of great importance in salt production. For history and details in general, see Veatch's article, La. Geol. Surv., '02, pp. 64-69.

Analysis of brine from Price's Salt Works, Winn Parish, La.
(By Maurice Bird.)

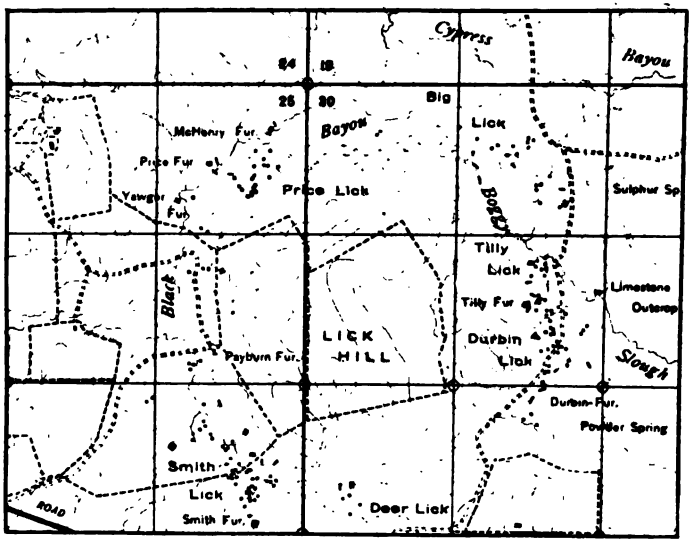
	Per hundred.
Sodium chloride	3.14
Calcium chloride	.079
Magnesium chloride	.138
Alumina	.050
Other solid matter	.030

RAYBURN'S SALINE.

Location.—Section 31, 15 N., 5 W., about eight miles from Bienville.

Size and Form.—See Fig. 18.

Geology.—From the southeastern part of this saline, Hilgard (Supp. and Final Rep't Geol. Rec. La. 1873, p. 30) reports 6 feet of crystalline limestone and 2 feet of gypsum. Veatch shows on Fig. 18 where Cretaceous fossils are to be found. He remarks: "On the little knoll east of the lick the soil is very black and waxy, with numbers of *Gryphaea vesicularis* and a few *Exogyra costata,* and pieces of selenite scattered over the surface. In the little gullies is exposed a very fine grained, white, chalk-like limestone containing a well-preserved Upper Cretaceous fauna. Limestone containing poorly preserved fossils is to be seen about half a mile north of the old works.



MAP OF PRICE'S SALINE, NORTH LOUISIANA

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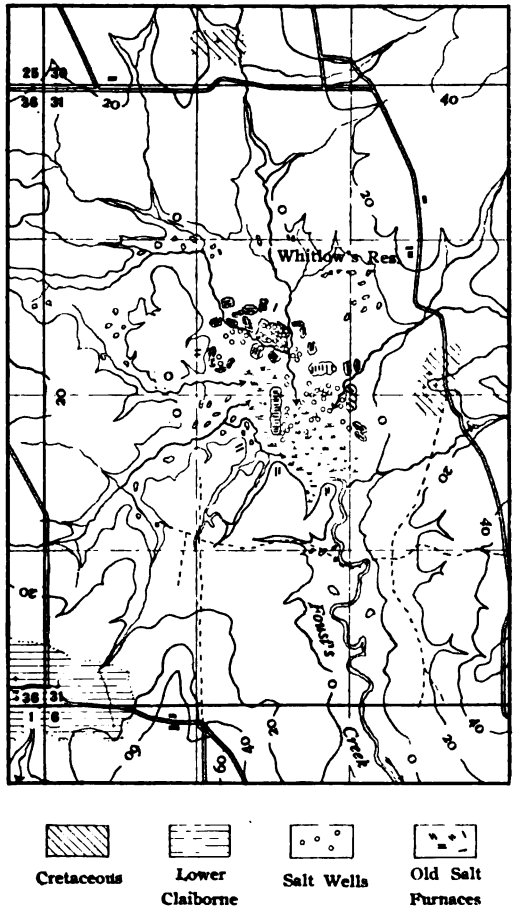


FIG. 18. MAP OF RAYBURN'S SALINE. BY A. C. VEATCH.

Most of these have been figured and described in the report of this survey for 1899, pp. 292-297, Plates 49, 50 and 51.

Production.—Although this saline as well as others in Louisiana is not producing salt, Veatch has figured that at one time it has yielded as high as 1,000 bushels daily. For a history of early operations, see La. Geol. Surv. Rep't '02, pp. 72, 73.

Analysis of Brine: Rayburn's Salt Works.
(Maurice Bird.)

Sodium chloride	4.60
Sodium sulphate	.022
Calcium sulphate	.322
Magnesium sulphate	.029
Alumina	.061
Other solid matter, partly in suspension	.030

KING'S SALINE.

Location.—Fourteen miles west of Rayburn's, on the low lands of Bayou Castor.

Size and Form.—See Pl. XXXIII.

Geology.—Gray fossilferous limestone fragments have been obtained from King's well. They show *Exogyra costata, Lima pelagica, Gryphaea vesicularis, Turritella trilira, Liopistha protexta,* and an *Anomia.* In Neil's well, half a mile northeast of King's well, where the Sparta-Coushatta road crosses the railway, between depths of 17 and 21 feet, dark, fossiliferous, sandy clays occur of typical Ripley Cretaceous aspect.

Production.—For "war-time" production and general history of this saline, see Veatch, La. Geol. Surv. Rep't, '02, p. 77.

Analysis of Brine, King's Salt Works.
(Maurice Bird.)

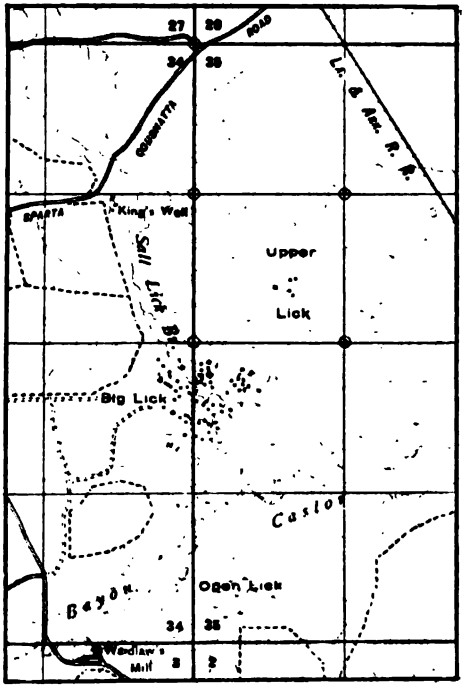
	Per cent.
Sodium chloride	6.940
Calcium sulphate	.010
Calcium chloride	.152
Magnesium chloride	.135
Alumina	.148
Other solids	.065

BISTINEAU SALINE.

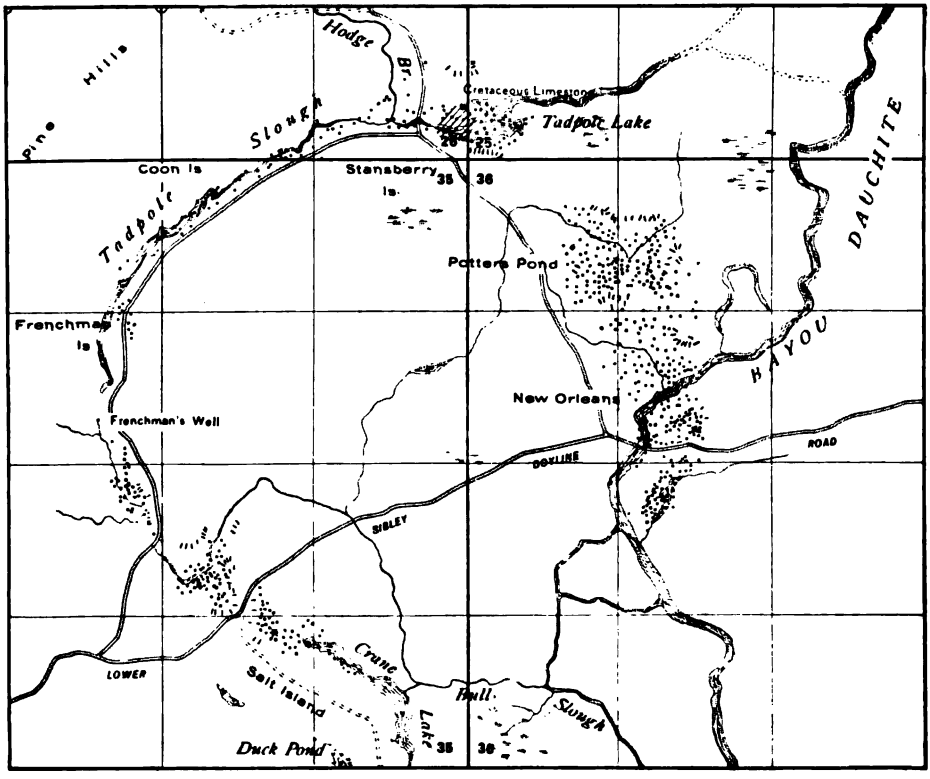
Location.—Lake Bistineau bottom; T. 18 N., R. 10 W., SS. 25, 26, 35, 36.

Size.—Largest of North Louisiana salines. See Pl. XXXIV.

On the northern edge of Stansberry Island there is an outcrop of yellow marl or very soft limestone. It extends almost to the government wells and contains large numbers of *Gryphaea*



MAP OF KING'S SALINE, NORTH LOUISIANA



MAP OF BISTINEAU SALINE, NORTH LOUISIANA
BY A. C. VEATCH

UNIVERSITY

vesicularis and *Exogyra costata,* both typical Upper Cretaceous species. A number of fragments of white, highly crystalline, fossiliferous limestone were found here, evidently taken from the wells. This limestone is lithologically very much like the highly crystalline limestone at Winnfield and contains the fauna found in the soft, chalk-like limestone at Rayburn's.

It is reported that during the war a deep well was bored near the mouth of Hodges creek. This well at a depth of 125 feet struck a rock which they could not penetrate. The precise location of this well could not be learned, but from its approximate location it would indicate the westward component of the dip at this point to be not less than 9° nor more than 20°.

Production.—Large quantities of salt were produced here during the Civil War. For particulars regarding methods of production, as well as details of the saline in general, see Veatch's Report. La. G. S., '02, p. 83.

Brine Analyses: Bistineau Salt Works.

(Maurice Bird.)

	Bryan's Well.	Potter's Pond.	Head of Salt Island.
Sodium chloride	8.450	7.810	3.800
Calcium chloride	.234	.301	.081
Alumina	.056	.052	.056
Other solid matter	.088	.061	.058
Magnesium chloride	.102	.156	.083

GRAND SALINE.

(See Chapter 4, Texas, *Grand Saline.*)

Location.— Van Zant County, on Texas and Pacific Railroad.

Size.—One mile east and west, and one-half mile north and south.

Geology.—Dumble gives depth to salt, 225 ft., and thickness of salt penetrated without reaching bottom. Veatch regards the salt as regularly bedded, showing no dome structure. See U. S G. S., Prof. Pap. No. 46.

Salt Production.—Brine from shallow wells evaporated for salt over 30 years ago; now better brine obtained from deeper wells. See Penrose Tex. Surv., 1st Ann'l, p. 35.

PALESTINE SALINE.

Location.—Six miles southwest of Palestine.

Size.—One mile east and west and one-half mile north and south.

Geology.—Surrounded by hills 60 ft. high, often showing white limestone with Cretaceous fossils. The limestone is capped with ledges of sandstone. See Penrose Tex. Surv., 1st Ann'l, p. 35. Rock salt penetrated here 104 ft.

STEEN'S SALINE.

Location—Smith's County, 14 miles north of Tyler, 5 miles east of Lindale, Carmona headwright.

Size.—A prairie, one-half to three-fourths mile wide and 1 to 2 miles long.

Geology.—Limestone outcrops, in surrounding hills from 30 to 60 ft. high.

Production.—Large quantities of salt were produced during the Civil War, employing 3,000 Confederate soldiers. (Herndon, 2d Ann'l Rept., Tex. Surv., p. 223.) Twenty furnaces made 12,000 bushels daily. It took 190 gallons to make one bushel of salt (Buckley).

BROOKS' SALINE.

Location.—Southwest part of Smith County, 17 miles southwest of Tyler.

Size.—One-half to three-fourths mile wide, 2½ miles long.

Geology.—Surrounded by Cretaceous hills (Herndon, 2d Tex. Rep., p. 223).

OIL CITY.

The oil investigations about "Oil City," Nacogdoches County, have proven nothing as to definite anticlinal or dome structure. The locality is of interest here mainly on account of its position on the southwest angle of the Sabine, Eocene peninsula already described.

GRAHAM'S AND STIVER'S SALINES.

These we have located from Hager's map.* Two others farther east he indicates without names. Note the general parallelism of the alignment of these salines with the lines dividing the Eocene stages. All are obviously of the same general character as the north Louisiana salines.

*Eng. and Min. Jour., July 28, 1904.

Though these domes may penetrate the base of the Oligocene series, it is a most interesting and noteworthy fact that practically the whole area where beds of this series occur at the surface is without domes.

DOMES; OR, STRUCTURAL PECULIARITIES OF THE SALT-BEARING LOCALITIES OF LOUISIANA AND SOUTHEAST TEXAS.

GENERAL STRATIGRAPHY OF THE MISSISSIPPI EMBAYMENT.

The stratigraphy of the area included under the well-known term *Mississippi Embayment* was early worked out in a general manner by Dr. E. W. Hilgard. The results of his labors east of the river were embodied in his "Agriculture and Geology of Mississippi," published in 1860; those west of the river in an article published in the American Journal of Science, 1869,* and in various subsequent publications. The main features of the geology of Louisiana, as well as easternmost Texas, were found to be, broadly speaking, what might have been expected from geology east of the Mississippi; yet, even at this early date, Hilgard recognized some remarkable features in Louisiana, having no counterpart in Mississippi. The Five Islands he had already studied and along with Thomassy and Gossmann had puzzled over their origin.† However, leaving the question of the local peculiarities aside, Hilgard, in 1869, had a fairly accurate knowledge of the general stratigraphy of the area here under discussion. That is, he then knew well that the general dip of the rocks in Louisiana was in a southeasterly direction, at right angles to the general strike of the Tertiary and Cretaceous formations, as shown in Texas, Louisiana and Arkansas; that if one should leave the Gulf coast and go inland, say up the Sabine or Red River, into the hill-land of north Louisiana, he would pass over the outcropping edges of older and older

*Amer. Jour. Sci., Vol. 46, p. 342, 1869.
†Vol. 48, pp. 331, et seq.

terranes. In other words, the southerly dip of the various terranes is greater than the slope of the land in the same direction. It is unnecessary here to go into details regarding Hilgard's and Hopkins' mistaken identity of the Vicksburg "group" in west Louisiana and their mistaken ideas regarding the stratigraphy of their strange "Mansfield group." Anyone desiring to see by what means and when these errors were corrected can consult the reports of this Survey for the years 1899, 1902 and 1905. The frontispiece, Plate I of the Report of 1902, gives the general scheme of formations of Louisiana, and the sectioned-model shown as Plate II of the same Report indicates clearly the way these formations are related some distance below the surface. In the present Report we wish to call special attention to the features referred to above as "remarkable," for herein lies almost a new field of research, one, too, that is to explain the origin of a great share of the mineral wealth of the State.

SALT, GYPSUM, SULPHUR AND LIMESTONE MASSES.

With a general idea regarding the stratigraphy of the State in mind, as stated above and as indicated in the illustrations just referred to, imagine near the surface of the several formations at localities shown by black spots on Plate XXIV, immense masses of rock salt, lenses of gypsum, limestone, sulphur, alone or in juxtaposition, superimposed one upon the other, having no regular shape or no fixed manner of bedding, drenched here and there with salt water, strained with oil and gas pressure in places to such an extent as to blow out drills, casing and all, from wells as soon as the imprisoned forces are reached and liberated.

Hilgard's Interpretation.—What is the meaning of such strange occurrences in a region of such generally monotonous and simple stratigraphy? Clearly these masses of material are foreign to the regularly bedded Tertiary and Quaternary sands and clays. This was pointed out by Hilgard as early as 1869. His earliest impressions, to be sure, regarding the salt of Petite Anse were that it had been concentrated in Quaternary basins or lagoons, but such ideas were quickly abandoned after he had made a reconnoissance of the salines of north Louisiana and

had not only seen something of the obvious tilting of the rocks about these areas, but had actually found Cretaceous fossils about their borders.

The outcrop of the regularly bedded Cretaceous terranes, it will be noticed, are many miles to the north and west of the north Louisiana salines. The association of salt with Cretaceous fossils and crystalline limestones, in north Louisiana, the occurrence of similar limestone in St. Landry Parish, the presence of sulphur and gypsum beds of great thickness in Calcasieu Parish, naturally led Hilgard to conclude that all these substances, foreign to the Tertiaries, should be classed with the Cretaceous. The piercing of many thousands of feet of Tertiary and Quaternary beds by "the peaks of a Cretaceous ridge" was indeed a bold supposition, yet one that seemed justified in the light of the geological knowledge of that time.

Hilgard frequently referred to this ridge as constituting the "backbone" of Louisiana, extending in a northwest-southeast direction.

Lerch's Explanation.—In 1893, Dr. Otto Lerch published, under the direction of the State Experiment Stations of Louisiana, "A Preliminary Report Upon the Hills of Louisiana." He had just visited and studied the salines of north Louisiana and had arrived at the following conclusions (*Op. cit.*, pp. 72, 73):

> At the close of the Mesozoic time enormous plutonic forces convulsed, fractured, faulted and folded the cretaceus strata, throwing up mountain chains of vast extent and raising them far above the waters of the gulf. It seems to us more than probable that these grand disturbances involved the whole of the southern Cretaceous, and that the enormous downthrow along the Balcones in Texas and the basaltic outbreaks along that fault are contemporaneous with the origin of the mountain chains in the Tertiary of that State and Louisiana. * * * * If we could remove the covering mantle of Tertiary and drift we would yet see the chains and peaks of limestone ranges formed at the close of the middle age of our planet, altered somewhat by later erosion and denudation.

Vaughan's Impressions.—Vaughan, in 1895,* failed to observe the evidences of orogenic movement described by Lerch, and says that "the Cretaceous strata at the Winn Parish marble quarry are almost horizontal, the limestone rising as a butte-like

*Amer. Geol., Vol. 15, p. 208.

mass into the Eocene." So far as north Louisiana is concerned, Vaughan seems to have reached the same conclusions as were maintained by Hilgard.

Lucas' Work.—At about this time there were many new facts coming to light about the peculiar Five Islands in south Louisiana. Largely this was due to the industry and agitation of one man, Capt. A. F. Lucas, whose training in the Old World had acquainted him with, and taught him the meaning of, somewhat analogous phenomena. While attempting to find artesian or some kind of "mineral waters" for Joseph Jefferson on Côte Carline, in 1896, Lucas hit upon a solid bed of rock salt at a depth of 290 ft.* In one instance a hole was bored to a depth of 2,100 ft. without passing through the salt mass. In 1897 Capt. Lucas found rock salt at Grande Côte and Belle Isle. Of these islands Lucas† briefly remarks:

> The geologic formation of this series of islands is undoubtedly Quaternary, while the salt deposits belong to the Tertiary period, and are supposed to rest on the Cretaceous.

The general result of his investigations, he affirms, has been to demonstrate the existence of relatively small and isolated beds of the best rock-salt thus far discovered on this continent, all of which are accessible by shafts for mining. The term "small" applies to their horizontal area only. What they lack in this respect, as compared with other known deposits, is overwhelmingly made up in their depth.

His sections across the salt islands showing the shape of the salt masses, would have been greatly enhanced in value if only exact data were given as to their location and direction.‡

Louisiana Survey Work Under Harris.—In 1898 the State Geological Survey work was reorganized and the present writer placed in charge, and Mr. A. C. Veatch was employed as assistant. The salines of north Louisiana were visited and studied, and, early in 1899, Veatch investigated the Five Islands. The results of this newly organized department were embodied in "A Preliminary Report on the Geology of Louisiana," usually referred to as "La. Geol. Surv., Rept. '99."

*Am. Inst. Min. Eng., Tr., Vol. 29, 1899, p. 469.
†Op. City, p. 465.
‡Op. City, p. 470.

Herein was brought out the important fact that in the best cases of faulting and folding observable, the Winnfield-Coochie district, there was rather a northeast-southwest trend than a northwest-southeast trend, as held by Hilgard. The presence of one continuous backbone, as described by that author, was declared disproven. Extensive orogenic movements were shown to have taken place in one of the Cretaceous areas at least after middle Eocene times. Veatch failed to find any definite proof of the origin of salt on the Five Islands or proof of the origin of the islands themselves. But his investigations on Belle Isle showed conclusively how very recently some of the orogenic movements have taken place. The Cretaceous age of the salt beds seemed perhaps most plausible, as Hilgard had long ago pointed out.

Lucas' Spindle Top Gusher.—More work was being done on the salines of north Louisiana in 1900 and 1901, when suddenly the commercial and geological worlds were astonished at the marvelous results of Capt. Lucas' boring on a slight rise of ground known as "Spindle Top," three miles southward from Beaumont, Texas. Oil at this place seemed to indicate that perhaps, although no salt was known at Spindle Top, there was some relationship betweeen oil and salt mounds and low domes and salines. The sulphur encountered indicated, furthermore, that there is something in common in this part of the world in the collection and segregation, if not in the origin, of salt, oil, gas and sulphur. Every low swell of ground, every known seepage of oil, every locality where gas was known to be issuing from the ground; in short, practically every spot that seemed to show the existence of what we now call *domes* at or beneath the surface was quickly leased; and from January 10, 1901 (Lucas' first gusher) to the present date drilling for oil has been prosecuted with remakable vigor. January 10, 1901, may well be considered the date of the commencement of our education regarding a new type of geological phenomena—we refer to the *origin and method of development of local dome structure.*

Dome Structure Explained by Gas Pressure.—Lucas* himself, to whom the credit belongs of starting this new branch of geo-

*Sci., Vol. 14, 1901, p. 827.

logical investigation, was inclined to think the dome structure of Spindle Top due to gas pressure from the great pool of oil 1,000 or more feet beneath the surface. He was, naturally, at that time unaware of the great mass of rock salt that we now know underlies this remarkable locality.

Harris' Early Views Regarding Spindle Top.—Our own impressions regarding the new geological problem propounded by the Lucas gusher were doubtless largely influenced by what we had learned regarding dome-structure in Louisiana. Shell fragments from near the bottom of the well seemed to belong to a very late Tertiary or Quaternary horizon. But specimens of so-called cap-rock seen in Beaumont indicated the very same type of porous limestone we were so familiar with in connection with Cretaceous uplifts and fossils in North Louisiana. Our conclusions, as expressed in the New Orleans Picayune March 27, 1901, ran as follows:

> The scanty evidence at hand would therefore indicate that the gusher is situated on the top of a Cretaceous anticline or fold, and that the pressure is from gas so commonly encountered in structures of this type. That the supply of oil is considerable cannot well be doubted, but that it will continue to gush long is very doubtful.

The Sheet Oil Explanation.—Other geologists, as late as May 29, 1901, clung to the strange idea that the pressure was hydrostatic and that the oil was to be found in extensive sheets throughout this part of the country. Note a communication to the Times-Democrat of the date just named:

> The well driller may experiment with safety in the Beaumont field without fear of structural complications, with a reasonable assurance that oil is apt to be found anywhere wihtin the region of the coast plain above the oil-impregnated sands. The oil should be found at decreasing depths at the rate of seven to ten feet per mile along the line drawn from Beaumont to Oil City, in southern Nacodoches county. The pressure and quantity will both likewise decrease away from Beaumont along this line.

However, the number of dry holes around and in close proximity to the Spindle Top Gusher, together with the fact that the many wells drilled showed a considerable doming of the oil-bearing beds in the center of the field, soon routed the adherents of simple structure for the localities where salt, oil, gas, sulphur and accompanying limestones are found in south Louisiana and

southeast Texas. E. T. Dumble, former State Geologist of Texas, sent a communication to the Secretary of the American Institute of Mining Enginers that was published in Vol. XXXI in 1902 (p. 1029 *et seq.*) of the Transactions, in which he argued for a Pliocene age for the oil-producing rocks of Spindle Top. He speaks of flexures to the north of Beaumont, but says nothing regarding the structure or extent of the Spindle Top field. He intimates the continuity of certain rocks of the region in the phrases: "The rock-salt and gypsum deposits of the coast country, extending southward to the Rio Grande * * * are simply a continuation of similar deposits in Louisiana."

Lucas Convinces Hill of Dome Structure.—The presence of anticlinal or dome structure at Spindle Top seemed very difficult for some geologists to grasp. Professor R. T. Hill admits in Science (Vol. XIV, Aug. 30, 1907, p. 327,) that it required a second visit to Spindle Top after a visit to Damon's mound, and Capt. Lucas' persuasive arguments, to convince him of the dome feature at this locality. He then concludes:

> One thing is certain, this oil occurs in underground pools, and another thing is probable, that the pools underlie dome-shaped anticlines in the new-made recent prairies. Furthermore, these uplifts are most probably due to isostatic movements rather than accumulations of gas.

Veatch Proves Dome Structure of Salines in North Louisiana.—Before summer of 1902, Veatch had completed a remarkably detailed survey of a large number of "salines" in north Louisiana and had fully determined the great probability that all possessed quaquaversal or dome structure. (See La. Geol. Surv., Rep't '02, p. 61 *et al.*) He also indicated the relationship of some of these structures to each other, and indicated thereby lines parallel to the Balcones faults of Texas. (See Pl. XXIII, '02.)

Harris Proves Great Uplift in Sour Lake Field.—The present writer was likewise in Louisiana in the early part of 1902 and studied the Anse-la-Butte and Jennings fields, and crossed over for a visit to Sour Lake. He there collected a good Jackson Eocene fauna from the material brought out near the bottom of a 1,500-ft. well and called attention to the great significance of this discovery in the Louisiana report of '02 (pp. 25 and 274).

It is obvious that if Jackson fossils are found in a well at Sour Lake, accompanied, by the way, by very hot water, while four miles to the southeast 1,900-ft. well flows only warm water and shows from its lowest drillings a Miocene or Oligocene fauna, there must be a most remarkable dip in this direction. This, so far as we are aware, is the only instance where Eocene fossils have been brought up in any drilling south of the Oligocene band shown on Plate XXIV.

EXPLANATORY HYPOTHESES.

Hill's Theory of Ascending Hot Brine.—In this same year Prof. Hill published an explanatory hypothesis of what he termed the "oil-phenomena" of the Coast Prairies. At this stage of the development of the study of dome structure this hypothesis was a very important contribution. Thomassy had long ago guessed at certain volcanic and hot-water phenomena that might have produced the salt masses of the coast. Capt. Lucas, however, had become convinced of the secondary character of not only oil and gas, but salt, gypsum, dolomite and so forth, distinguishing them from "the mother-strata or sediments out of which they had been produced."* Hill accepted Lucas' conclusions and explained, by his hypothesis, the source and distribution of the substances above enumerated in the domes of south Louisiana and Texas. His hypothesis reads:

*Frank. Inst. Jour., Vol. 154, p. 273, 1902.

The oil and salt pockets of the Texas coastal plain are probably not indigenous to the strata in which they are found, but are the resultant products of columns of hot saline waters which have ascended, under hydrostatic pressure, at points along lines of structural weakness, through thousands of feet of shale, sand and marine littoral sediments of the coast plain section, through which oil and sand are disseminated in more or less minute quantities. The oil, with sulphur, may have been floated upwards on these waters, and the salt and dolomite may have been crystallized from the saturated solution.

The channels of these ascending waters may have been in places of structural weakness, such as fissures, which probably at one time continued to the surface, but may have been sealed by the deposition of the latter overlapping strata now capping the oil pools. Such features, when occuring under gentle anticlines, may explain the collection of oil beneath the surface in pools.

There is much evidence that the present and former coast plains of Texas, marking the recedence of the old shore line of the Gulf of Mexico from the Rocky Mountain region to its present site, has experienced periods of pause, producing a series of concentric shore

lines, accompanied by faulting. It is a significant fact that in another part of Texas, adjacent to a region which was at one time a coast line of the Gulf of Mexico, there exists such a line of weakness. The great Balcones fault, which the wrtier has frequently described, is of this character. It is very probable that, along the present coast line, similar faulting took place in Eocene time, and that the evidence thereof has been obscured by overlapping of the Grand Gulf and later formations which veil the coast prairie.

If these deeply embedded water-bearing strata, under tremendous hydrostatic head, exist beneath the coast prairie, their waters would pass through any natural channels, such as fault-fissures, through all the known sheet-oil horizons of Texas, except those of the Carboniferous formation. Such hot water would gather from the rocks, which are known to contain them, oil, salt, lime, sulphur and gypsum; and the oil gathered from these strata would be floated on the ascending saline waters.

If ascending columns of oil and water of this character should meet resistance near the surface, we could well conceive of the formation of such a pool as that beneath Spindletop Hill. To produce such a formation, which would be practically like the end of a "mushroom" bullet, there must be resistance; and this resistance would naturally come from an impervious formation. The overlap of the X [Neocene] beds of the coast prairie, stopping the free exit of the water upward through the faultlines, would produce such a resistance; and this overlap is believed to have taken place.

At any rate, should such a column of ascending water, with oil on top of it, reach a resistance near the surface, a subterranean pool of oil would result, such as we find at Spindletop. Furthermore, the reaction which would take place in the column of water below the soil could theoretically account for all the after phenomena of the coast prairie mounds, such as the Salt Islands of Louisiana and Damon's Mound, and the dolomite of Big Hill.

It is a remarkably interesting fact that in the mammoth spring of the Balcones fault zone, between Austin and Del Rio, we have an analogous group of data showing the rise of subterranean water in spots along a line of faulting. Along this line great columns of water are now rising, not continuously, but in spots, like the supposed ancient artesian springs at Austin, San Marcos, New Braunfels, San Antonio, Fort Clark and Del Rio.

It is true that these waters do not bring any perceptible oil to the surface; but this is easily explained, since they pass mostly through limestones and non-bituminous strata. On the other hand, had they been, as the old structure of the coast prairie has been, overlapped by more recent formations, they would constitute columns of suppressed water, like those we have theoretically supposed beneath the coast prairie.

A remarkable discovery has been made within the past few weeks, indicating the correctness, from a scientific point of view, of Captain Lucas' theory that the mounds were the loci of his groups of oil phenomena, and supporting the hypothesis of ascending waters. In Brazonia county, Texas, some 350 miles west of Belle Isle, Louisiana (almost as far as Philadelphia from Cleveland), the lonely mound known as Damon's Mound, similar to those of the Louisiana Salt Islands, rises out of the prairie. This has been penetrated, and proven to be an anticlinal dome similar to that of Belle Isle, with a similar stratigraphic section: Pleistocene sand and clay, with traces of sul-

phur in the surface layers; oil, then sulphur, and for its lower 700 feet pure rock salt, with occasional traces of oil, demonstrating the occurrence of the latter substance, but not in commercial quantities.

Now the question raises, is Damon's Mound a fossil oil hill, beneath which the oil existed but has passed away? If so, why not also the Five Islands and other salt islands of Louisiana?

To appreciate the full value of Hill's suggestive theory one must consult his original article. But the outline of the principal points of its bearing on salt-mound formation may, we hope, be gathered from the above quotations. In passing, one cannot help noticing the very rapid shifting of Hill's ideas regarding the geology of the Coastal Plains, especially as regards the oil-salt localities. May 29, '01 (see Times-Democrat quotation above), he was unaware of any structural peculiarities in the Coast Prairie. In August, '01 (see reference to Science above), with Lucas' aid he admits "dome-shaped anticlines," but does not think they were produced, as Lucas did, by gas pressure, but by "isostatic movements." Finally, May 14, '02, at the joint meeting of the American Institute of Mining Engineers and Manufacturers' Club (see Jour, Fran. Inst., as quoted at length above), although faults and monoclines are inferred to exist below the coast late Tertiary and Quaternary formations, he seems to suggest that the real local mound or dome-producing force is the hydrostatic pressure of columns of hot salt water and oil. However, we believe his unconditional acceptance of Lucas' idea that salt, gypsum and attendant substances so intimately associated in Louisiana and Texas domes are the result of secondary replacement, and his own assertion that the replacement has been brought about through "the agency of the ascending circulation of saturated briny waters" do him credit and go a long way toward explaining the dome-structure of this section of the country.

Kennedy and Hayes' Contribution.—Perhaps since the date of the Lucas' "gusher" no geologist has been in the field, in direct contact with every-day developments, more continuously than Mr. William Kennedy of Austin, Texas. A joint paper by himself and Dr. C. W. Hayes of the U. S. Geological Survey appeared in 1903 as U. S. Bulletin No. 212.

Looked at from the standpoint of increasing our knowledge of dome-structure this report contains several good points. The

collection and correlation of facts so that definite sections across Spindle Top could be made (see Fig. 2); the recognition of an interrelationship of the various domes along certain lines (see their Pl. VII); the admission that the domes are structures of a wholly different class from the Appalachian anticlines; the somewhat hesitating admission that "it may therefore be necessary to refer their origin to supersaturated solutions coming through fissures opened along a fault line. These we believe to be helpful facts and suggestions in the right direction. On the other hand we have not the slightest faith in the reliance placed by these authors in determinations of the horizons penetrated at Spindle Top by various paleontologists. *Nassa beaumontensis* is, so far as we can judge from Aldrich's description, no more nor less than the common and well-known recent *N. acuta.* Neither *Tornatina canaliculata, Turbonolla, sp.* nor young *Mactra* furnish any clue to the Pliocene age of the beds from a depth of 390 ft. Nor does *O. virginica* mean Miocene more than Pliocene or recent. Nor do *Ostrea, Turritella,* and *Mactra* in any way mean Eocene or Miocene. In fact, so far as we can judge, no palentological evidence, as published in Bull. No. 212, has been deduced to show the beds penetrated at Spindle Top from surface to cap-rock other than Pleistocene or recent deposits. Again, it seems a little peculiar that Bulletin No. 212 should be published in 1903, and that both authors should have been in the field early in 1902, and that in the summer of 1902 Report of the La. Geol. Surv. '02 should have been published containing an account of a most interesting and remarkable fauna at one of the Sour Lake wells, based on fossils collected early in 1902; yet we read in Bull. 212, p. 118:

> No fossils have been obtained from any of the wells thus far drilled and it is therefore impossible to make definite statements regarding the geologic horizon of the oil-bearing sands. It appears probable, however, that the principal productive horizon is the same as that at the Spindletop pool, although the character of the beds is different. Not enough drilling has yet been done in this district to determine its limits or its structure except in a very general way. The indications point very strongly to an anticlinal or dome structure, similar to that of the Beaumont pool. The deformation appears to be less abrupt in this case, and it has influenced the surface contours only to a very slight extent.

Moreover, though on Pl. VII there are suggestions that there is some kind of relationship between mounds of a northeast-southwest alignment, the equally obvious relationship along northwest-southeast lines is not indicated.

Coste's "Volcanic Origin of Petroleum."—In 1903 Eugene Coste read before the Canadian Mining Institute an important paper on the volcanic origin of natural gas and petroleum. He remarks (p. 17, author's ed.): "On this continent in the newly discovered oil fields of Texas and Louisiana, and also in the California fields, we have many no less direct evidences of vulcanism, though they do not appear to have been understood in their true light. These are in Louisiana and Texas, the Salt Islands and the 'Mounds' of the Coast Prairie such as the famous 'Spindle Top,' near Beaumont, which are clearly nothing else but 'suffions' or 'salses,' hardly extinct yet, grouped along fractured lines and marking in that region the dying out of vulcanity; that is to say, the dying distant echo of that tremendous volcanic energy, which, a little farther south in Mexico, Central America and in the islands along the south coast of the Caribbean Sea, is to this day so powerfully active."

Again (p. 31), we "claim that this line of faulting gave access to volcanic emanations bringing the water, salt, sulphur, oil and gas from the interior in the state of vapors and gases which condensed more or less near the surface. some escaping yet in their gaseous state as the hydrogen sulphuretted and natural gas."

It will be noticed that salt and salt waters are only incidentally mentioned in this paper. But enough is said to show that the author believes them to be of volcanic origin along with oil and gas. He leaves us entirely in the dark as to why vapors should condense "more or less near the surface," how "mounds" and "salt islands" are built up, or what the direction and location of the "lines of faulting" may be. Some salt we know to be of volcanic origin. But the majority of the vast salt sheets embedded in the rocks have been precipitated from condensing sea-waters. We are inclined to suggest that there may also be more than one way for accounting for the immense quantities of petroleum and natural gas stored away in the earth's crust.

Hager's Volcanic Plug Theory.—In the Engineering and Mining Journal for July 28, 1904 (pp. 134, 180), appears a very important contribution to the domes of the region under discussion by Lee Hager. Though the title of his article is "The Mounds of the Southern Oil Field," he maps and refers to practically all the domes (oil fields, "islands," buttes and salines) between the Mississippi and Colorado rivers. This is the first résumé of dome structure in the broad sense used in the present publication.

A thorough comprehension of the subject is admirably shown in Hager's summation as follows:

1. The Cretaceous salines in Northern Louisiana and Texas, the Eocene salines of the Sabine river and other localities, the upper Tertiary salines and mounds near the Gulf—all present the same conditions of geological structure, and are probable due to the operation of the same natural causes.

2. All of these localities represent areas of uplift, with considerable but varying degrees of faulting, plication and displacement. The area affected in every case is limited. The surrounding country rocks show no considerable deformation.

3. Horizontal compression alone is inadequate to produce such conditions of structure; the thrust must have been mainly from below.

4. All of the mounds and salines thus far prospected have shown the existence, singly or in combination, of certain phenomena peculiar to these localities—salt, gypsum, sulphur, dolomite, petroleum, sulphuretted hydrogen, sulphur dioxide, hydrocarbon gases, hot sulphurous and saline waters and metallic sulphides.

In searching a cause for all these conditions and phenomena, Hager seems to feel that Hill's theory, as already quoted, may account for the *materials*, but *dome-structure* is very ill explained by columns of hot water and oil under hydrostatic pressure, sealed and held down by a comparative superficial, impermeable late Tertiary or Pleistocene layer.

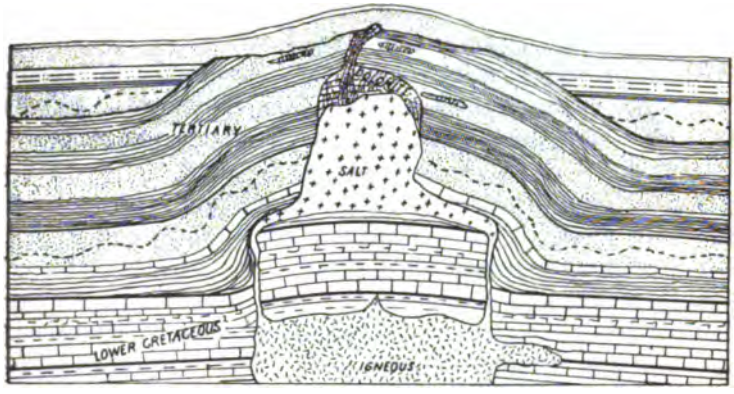
Whether Hager's hypothesis as outlined below will bear the results of future research or not, he deserves much credit for not only seeing the whole subject in a broad and philosophic light, but attempting to substitute a better hypothesis for the weak point of Hill's theory, namely, some reasonable cause for dome structure. Again, another important step in advance is taken by Hager. He clearly states that the deep-down, underlying rocks are "involved in the dome-like folding."

No one can appreciate Hager's article without seeing and reading it all, several times; but we can only give here what he styles the "bald outline" of his hypothesis:

The movement which resulted in the great Balcones fault, or a similar movement in late Tertiary times, extended to the rock sheets below the present coastal plain, accompanied by igneous activity, as in the vicinity of the fault itself. Fault blocks resulted, thrust up by intrusive masses of igneous material in the form of laccoliths at great depth. Owing to the nature of the Tertiary deposits, yielding clays, marls and quicksands, the faulting proper was confined to the deep-lying indurated lower Cretaceous and Carboniferous rocks. In the unconsolidated materials of the overlying Tertiary and upper Cretaceous dome-like structure resulted, due to the vertical thrust of the fault blocks pushed up by the intrusive masses in the form of laccoliths.

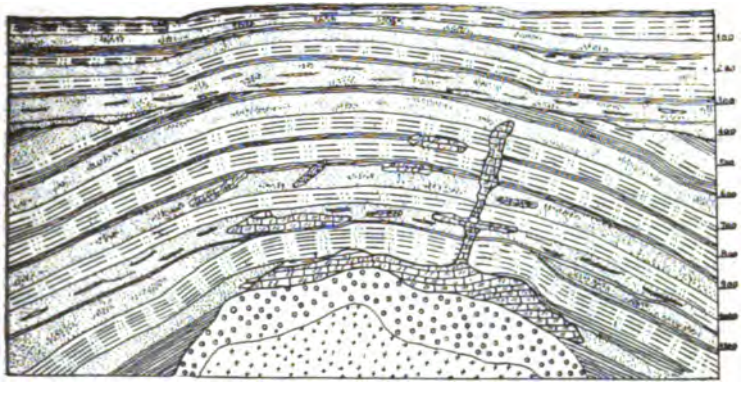
By contact with the molten instrusives, vast quantities of gas were generated from the reduction of metallic sulphides and the distillation of lignites and organic substances. These gases, accompanied by steam under tremendous pressure, forced their way to the surface through the unconsolidated sands and clays of the overlying Tertiary material, perhaps giving rise to mud volcanoes, such as occur in many of the world's great oil fields of the present day. Heated waters from great depths found vent along the same channels, carrying in solution carbonates of lime and magnesium, gypsum and salt. By ebullition any evaporation these solutions became concentrated until, saturation resulting, precipitation commenced, forming the neck-like masses of salt, sypsum and dolomite now encountered with the cooling of the intrusive masses and the choking of the vents, the process practically ceased. A period of subsidence followed, during which the coastal Quarternary beds, which at present cap the mounds, were laid down, followed by a secondary movement along the old lines of weakness, resulting in the present elevation of the mounds above the surrounding prairie.

The function of these quaquaversal areas of uplift in determining the accumulation of petroleum into productive pools is an open question. It is possible that the fault lines may have furnished vent for the ascent of petroleum from the deep-lying oil horizons of the Cretaceous and Carboniferous. It is possible that the presence of intrusives may have assisted in the process by the distillation of organic material. It seems more probable, however, that the oil is indigenous to the Tertiary deposits, to some degree petroliferous in all horizons, and that the mounds but furnish the dome-like structural conditions requisite for the accumulation and storage of oil. (See Figs. 19 and 20.)



HYPOTHETICAL SECTION OF TYPICAL MOUND

FIG. 19.



SECTION OF SPINDLETOP

LEGEND

SALT DOLOMITE CLAY SAND SHALE GYPSUM

FIG. 20.

Hager himself remarks that the weakness of the above-outlined hypothesis lies in the assumption of intrusives, the existence of which we have no evidence whatever. However, his many citations of the occurrence of salt, oil, gypsum, etc., in connection with mud-volcanoes and other igneous manifestations, he doubt-

less feels lend a strong plausibility to the former occurrence of such activities in Texas and Louisiana.

We find it very hard to conceive of "ebullition and evaporation" taking place and crystallizing a few billion tons of salt in one neck, almost unmixed with foreign matter like masses of gypsum, limestone or dolomite elsewhere, all from the heat of a supposed plug far below; then a sinking and covering of the mass, then finally a re-elevation in such a manner as to push the old plug up and produce a dome at the surface. It seems to us there are here a great many very questionable suppositions. Hager seems to have ignored almost entirely the probable relation of the different domes to each other. Doubtless he felt that an igneous plug could be pushed up in most any place, regardless of similar activities in adjacent districts.

Veatch Proposes a Volcanic Theory.—Veatch*, while working on the underground water resources of northern Louisiana and southern Arkansas, developed a theory for the formation of domes very similar to that proposed by Hager.

Fenneman's Work.—In 1906, what may be styled a revised edition of Bull. 212 of the U. S. Geol. Surv., was published as Bulletin 282 by M. N. Fenneman; this author having spent three months in the field during the summer of 1904. In a former part of this chapter we have had occasion frequently to refer to this author's work regarding more recent oil developments in the Texas fields.

After tabulating the characteristic materials of the Coast Plain domes, he concludes:

> The normal order of depth of the materials in the mounds or oil fields is as follows:
>
> 4. Unconsolidated sediments.
> 3. Porous limestone.
> 2. Gypsum.
> 1. Salt.
>
> While the position of the sulphur varies, it is most frequently found in or near the limestone. Petroleum is associated with the porous limestone and the overlying sediments.

As a rule, however, Fenneman's report is of value chiefly for the details given as to substances penetrated in each and every oil-field along the coast. Not being acquainted with the more evident characteristics of dome-structure as shown in

*U. S. G. S., Prof. Pap. No. 46, pp. 29 and 67, 1906.

north Louisiana and the Five Islands on the coast, his general inferences shed little light upon the subject. He lays much stress on the peculiar local development of rocks, their thinning out and disappearing in short distances, passes lightly over the subject of crustal disturbances, feeling evidently that such ideas are based largely on a "supposed analogy with certain salines of Louisana and east Texas, where the quaquaversal dip is marked, but where crustal deformation is manifestly far more intense than at this point" (Spindle Top). He believes the strata underlying the Sour Lake fields "are approximately horizontal" (p. 44) and that "it may be stated as a general principle based on observation that steep dips in the oil-bearing mounds are limited to the limestone (or dolomites) which have been precipitated from water. The dense, hard plates due to cementation are, so far as known, nearly or quite horizontal. This statement does not apply to the higher mounds, which have not as yet produced oil" (p. 45).

Regarding the Hager hypothesis quoted as some length above, Fenneman has this to say:

> Many facts may be adduced in support of this hypothesis, although it must be admitted that it presents some serious difficulties. The mode of accumulation of of the enormous masses of rock salt which occur in the Louisiana Salt Islands, in Damon Mound, in High Island, and also in Spindletop has never been satisfactorily explained. For a variety of reasons it does not seem possible that they can be the result of evaporation of sea water in natural salt pans, which is supposed to be the origin of most deposits of rock salt. It may therefore be necessary to infer their origin to precipitation from rising ground waters, though no possible reason has yet been suggested for the precipitation of the salt.

Finally, as regards the interrelationship of domes. he has but this to say:

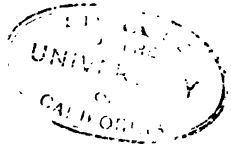
> There is some reason for thinking that such structures are ranged along lines of slight crustal deformation or disturbance. If such lines exist, they probably trend northeast and southwest. This probability may well be recognized in prospecting for new fields.

Dome Structure Produced by Growing Crystals.—In the summer of 1907 we published Bulletin No. 5 of the Louisiana Geological Survey, entitled "Notes on the Geology of the Winnfield Sheet." In the six townships covered by this "sheet" there are three well-defined areas that bear the ear-marks of dome structure. In discussing such structures we suggested a very differ-

ent way for accounting for the uplifting of domes from any thus far presented, so far as we are aware. In place of the necessary pressure being furnished by gas, or oil and water under a heavy head, or in place of purely hypothetic igneous plugs, we appealed to what ultimately amounts to the power of growing crystals. We believe there is practical unanimity now amongst geologists regarding the secondary nature of the salt masses so frequently met with in Louisiana and Texas domes. In nearly every case, we believe, the various writers quoted above have come to this conclusion independently and in spite of very strong early inclination toward a normal or "salt-pan" origin. We believe all will admit that water has been the dissolving and transporting agent. The main difficulties in the whole matter have been: First, how can rising columns of water be made to precipitate their salt, even though saturated and, second, what is the force that lifts up a certain hundred or thousand feet of superficial strata in limited areas, almost never two miles across? The remarkable circular form of the domes, and their quaquaversal dips and the extent of their proven vertical movements in comparison with their diameters—these, too, are troublesome factors.

In brief, we answer, first, *precipitation is due to decrease in temperature;* and, second, the requisite *uplifting force* is amply accounted for by the *power of growing crystals.*

The reason for supposing that the power of crystallization has been so potent in dome formation were forced upon us while working in the Myles salt mine on Grande Côte. Mention has already been made of certain streaks noticeable in both the Myles and Avery mines. These streaks, often very faint, have been spoken of usually as lines of stratification. But they seem not to be such on close examination. Their vertical, or nearly vertical, position in many places of course would not debar them from being true bedding planes, for it is quite conceivable that some salt starta have been highly tilted and much deformed. But there are concentric circular figures alone in white banks of salt, as already shown in Fig 8, that look more like slight discolorations due to the infiltration of waters carrying impurities. The crystals about such places show, so far as



UNIVERSITY OF CALIFORNIA

GYPSUM QUARRY TWO MILES WEST OF FAYETTEVILLE, N. Y. HARRIS PHOTO

Showing syncline caused by the solution of underlying salt and gypsum beds.

UNIVERSITY OF CALIFORNIA

THE LAST OF THE OLD KETTLE EVAPORATION PLANTS IN NEW YORK STATE

HARRIS PHOTO

UNIVERSITY OF CALIFORNIA CITY

formed. Hence the marvelously restricted areas of these salt masses in comparison with their depth. Naturally it is taken for granted that in the comparatively slow growth of domes by this process, erosion at the surface would prevent any unusually sharp and elevated hill being formed that would largely increase the pressure at the base of the salt column. It may also be taken for granted in the simple case supposed that the area is neither sinking nor rising to any considerable extent. For it is evident that if the area were, for example, sinking, and receiving deposits above, the isogeotherm that passed through any given point before depression would seem to gradually rise as depression went on. Since the precipitation of salt, under conditions now being considered, is a matter of decrease in temperature, as may be inferred from Fig. 21, the horizon at which salt would be precipitated would also seem to rise; that is, there would be formed a second bed of salt above the first. Note in this connection the 70-ft. bed of muck and logs between salt layers in the deep salt well on Petite Anse.

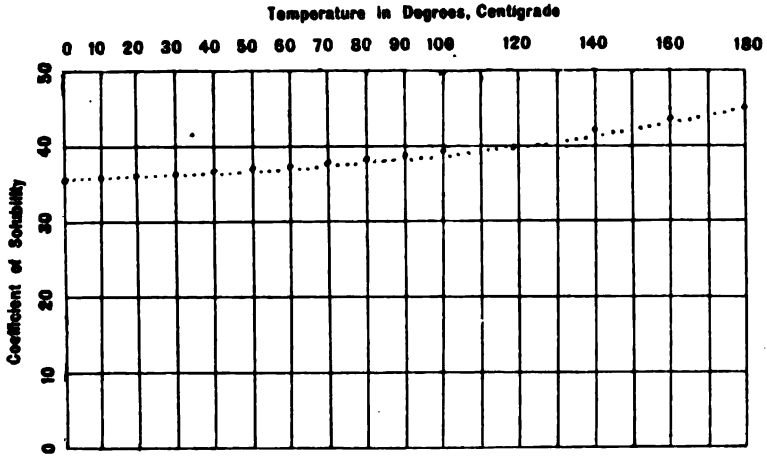
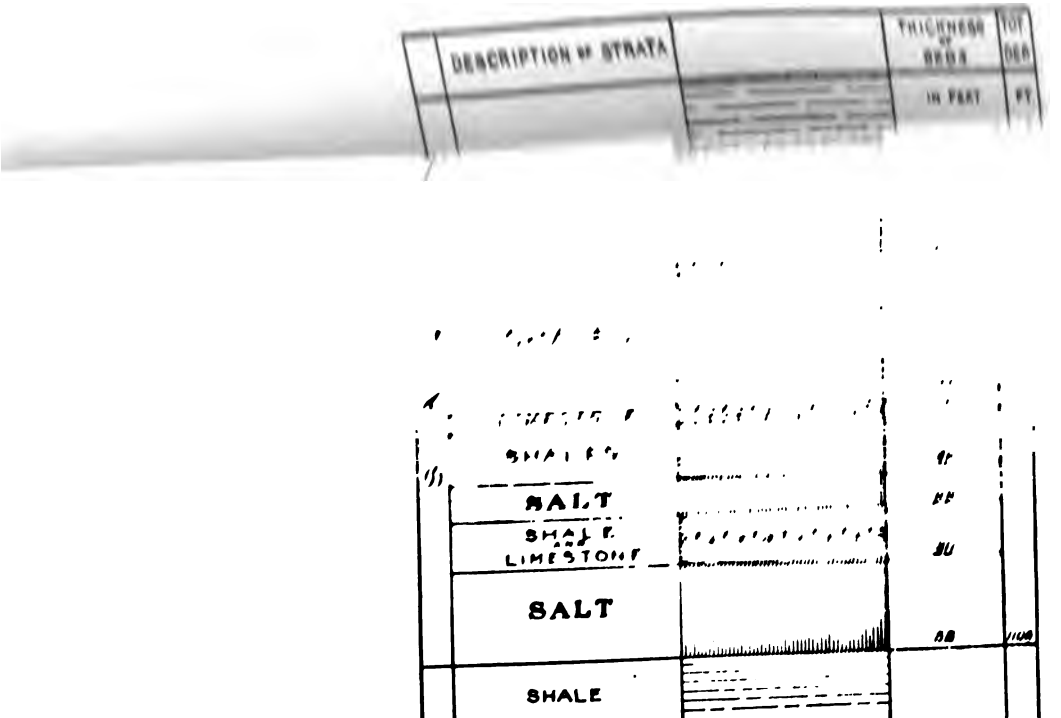


FIG. 21. SHOWING INCREASE OF SOLUBILITY OF SALT IN WATER WITH RISE OF TEMPERATURE.

Constructed from data given in Seidell's Solubilities, etc., 1907, p. 299.

If brine were saturated at a temperature of 180° C. and the pressure were not so great but that salt crystals could be formed


DESCRIPTION OF STRATA
THICKNESS IN FEET
TOTAL DEPTH IN FEET
SHALE
SALT
SHALE
LIMESTONE
SALT
SHALE

from the ascending brine where the temperature was reduced to, say, 160°, then and there precipitation, crystallization and dome-structure would be begun. However, as the weakened solution rose, it would be lowered in temperature and would continually give off salt. Hence, though the salt column were slender at first, doubtless in course of time it would be more than apt to become in a general way cone-shape, with the point upward. Different conditons would naturally modify the form of growth. Other substances might similarly be formed in various shaped masses, as dolomite, gypsum, anhydrite, calcite, sulphur, all tending in one general direction, the formation of dome-structure. How important these structures are in this region for the collection and retention of oil and gas in commercial quantities, all know; it is not our purpose to treat this side of the subject here.

How completely the upward movement of a cone-shaped mass from depths of perhaps 1,000 to 3,000 ft. explains the steep quaquaversal dips about the salines (and oil-domes so far as they have been made out) only those familiar with the phenomena in the field can appreciate.

DOME TAXONOMY.

The Mississippi Embayment a Great Pitching Trough.—Now, a word as to the general arrangement of the domes, their relations to one-another. First, let it be remembered that the Mississippi Embayment region is, structurally, a great pitching trough. Though the general dip of the strata must be southward, beds cropping out east of the Mississippi dip southwesterly, those west of the Mississippi, southeasterly. The dip is far greater than the slope of the land. Waters entering along the outcropping edges of the Tertiaries and Cretaceous and following bedding planes southward are soon thousands of feet beneath the surface. Facts from surrounding areas lead us to suppose that beneath this pitching trough there are Paleozoic and Mesozoic strata, fractured in different directions, strata oftentimes highly impregnated with salt.

The Sabine Peninsula.—As the material was being laid down in this old trough, slips along fault lines occurred, owing to differential loading perhaps. Notable among the blocks lifted or

left above surrounding areas is the one styled "Sabine Peninsula" on the map (Pl. XXIV). As a rule, however, the embayment area lengthened or shortened as movements up or down took place, through faulting in a northwest-southeast or a northeast-southwest direction. Some of these lines may have been marked out in Paleozic time, but it is quite probable that most of them are genetically related to the loading of a V-shaped area styled the Mississippi Embayment.

Two Series of Fault Lines.—Note on the map the direction of the Balcones fault, the Red River-Alabama Landing fault, the alignment of the east Texas salines, the hovering about the margins of the "Sabine Peninsula" of a large number of domes, the remarkable alignment of the Five Islands, the deflection of the Mississippi River from above Baton Rouge to the Gulf, the crisscross arrangement of lines through the domes in southeast Texas.

Oligocene Area Devoid of Domes.—Another most significant fact in the arrangement of the domes is their avoidance of Oligocene areas. As an explanation of this last fact we venture to suggest that the Grand Gulf sandstones and clays were in part, at least, subaerial in origin and of a greater thickness than the synchronous off-shore deposits farther south. Subsidence doubtless went on most rapidly where the greatest amount of matter was accumulating, *i. e.*, near the Gulf margin of that time. Farther to the south, as well as to the east (Georgia), and west (east Texas), beds which would seem to be of Grand Gulf age, at least upper Oligocene, have afforded slightly brackish water and purely marine fossil remains. The heavy sandstone beds of the typical barren Grand Gulf are evidently of slight north-south amplitude. At some wells in the Sour Lake oilfields Jackson Eocene fossils are found at depths from less than 1,075 to 1,500 ft. In others, a new fauna belonging somewhere between the Vicksburg and the lower Miocene is found between depths from 700 to 850 ft. In this uplift there are no record of Grand Gulf sandstone, nor Vicksburg clays and limestones. It seems, then, that the deep, synclinal Oligocene trough filled with clays and indurated sandstone constitutes a zone unfavorable to the upward tending oil and salt waters.

Age of Domes.—As to the age of the various domes, it seems to us that they were formed whenever conditions were favorable. Whenever an ascending solution, saturated at a high temperature, was brought in contact with higher and cooled rocks, precipitation took place, crystals were formed and dome-structure began. It is very likely that, although some saline columns of hot water may have ascended from mere fissures in the deep-lying Mesozoic beds, it is more than probable that when one fissure, fault, or sharp anticline was traversed by a second, nearly at right angles to the first, a place would be sufficiently ruptured for the upward passage of ascending waters. By consulting the map it will be seen that Beaumont, for example, is evidently located at such a crossing. Doubtless there are many fault-lines in the field not indicated on the map; and it may be that some of them so indicated are not real. But the general conception of Mississippi Embayment geology as outlined above, with its two-fold system of faults or sharp anticlinal ridges, rests, we believe, on a secure basis.

We are inclined to think that the results of some tangential pressure may be noted here and there along these structural lines, causing the deep-lying Mesozoic or Palezoic strata to rise up in places considerably above their normal position. This we believe would be the case, especially at the crossing of two structural lines approximately at right angles to each other. Hot waters from profound depths could then easily and quickly reach higher and cooler horizons, and precipitation, crystallization and dome structure would move on apace. The growing nuclear mass would in such cases simply push aside and turn back the four corners of the older low-lying rocks, lifting up only the newer beds immediately above. Facts have already been observed that seem to indicate that such is the true history of

Long ago we called attention to the peculiarities in terrestrial magnetic forces about the area of the Sabine peninsula. Graphically they are faintly indicated on Plate XI of Bulletin No. 2, Report for 1902; also Plate 2, Bulletin No. 5, Report of 1907. From New Orleans to Colfax, where observations have been somewhat numerous, there is an irregularity of amount and direction of magnetic forces shown on Plate XI, already refered to, that seems to us to be in harmony with a somewhat complicated substructure for this part of the State. This whole subject needs careful attention, for it may lead to practical results.

left above surrounding areas is the one styled "Sabine Peninsula" on the map (Pl. XXIV). As a rule, however, the embayment area lengthened or shortened as movements up or down took place, through faulting in a northwest-southeast or a northeast-southwest direction. Some of these lines may have been marked out in Paleozic time, but it is quite probable that most of them are genetically related to the loading of a V-shaped area styled the Mississippi Embayment.

Two Series of Fault Lines.—Note on the map the direction of the Balcones fault, the Red River-Alabama Landing fault, the alignment of the east Texas salines, the hovering about the margins of the "Sabine Peninsula" of a large number of domes, the remarkable alignment of the Five Islands, the deflection of the Mississippi River from above Baton Rouge to the Gulf, the crisscross arrangement of lines through the domes in southeast Texas.

Oligocene Area Devoid of Domes.—Another most significant fact in the arrangement of the domes is their avoidance of Oligocene areas. As an explanation of this last fact we venture to suggest that the Grand Gulf sandstones and clays were in part, at least, subaerial in origin and of a greater thickness than the synchronous off-shore deposits farther south. Subsidence doubtless went on most rapidly where the greatest amount of matter was accumulating, *i. e.*, near the Gulf margin of that time. Farther to the south, as well as to the east (Georgia), and west (east Texas), beds which would seem to be of Grand Gulf age, at least upper Oligocene, have afforded slightly brackish water and purely marine fossil remains. The heavy sandstone beds of the typical barren Grand Gulf are evidently of slight north-south amplitude. At some wells in the Sour Lake oilfields Jackson Eocene fossils are found at depths from less than 1,075 to 1,500 ft. In others, a new fauna belonging somewhere between the Vicksburg and the lower Miocene is found between depths from 700 to 850 ft. In this uplift there are no record of Grand Gulf sandstone, nor Vicksburg clays and limestones. It seems, then, that the deep, synclinal Oligocene trough filled with clays and indurated sandstone constitutes a zone unfavorable to the upward tending oil and salt waters.

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some domes. It would seem that perhaps, after all, the Mesozoic and even Paleozoic rocks are, in some instances, in limited areas, not so far beneath the surface in Louisiana as has often been supposed, and that salt, as well as oil, sulphur, gypsum, etc., of the "mounds," "islands," "sour lakes" and "salines," though often flowing into Tertiary or Quaternary reservoir, originate in beds belonging to an earlier period of the earth's history.

OCCURRENCE OF SALT DOMES ELSEWHERE.

Alabama.—We strongly suspect that there are interesting anticlines accompanied by dome structures in or about Clarke County, Alabama. Years ago, in this county, salt was obtained from wells and springs and evaporated in old sectioned boilers or kettles in precisely the way described by Veatch in North Louisiana. See Bull. No. 43, U. S. Geol. Surv., 1887, p. 38.

Europe.—To what extent the enormous deposits of north Germany have been thickened locally by secondary deposition, it is impossible to state without careful local study. In Transylvania, however, the egg-shaped mass at Maros-Ujvar (Pl. LIII, B), can with little doubt be referred to as having been formed after the manner already described for the salt masses of Louisiana. The salt masses of Roumania perhaps belong to the same category.

Under the heading "The Pyrenees" of this report will be found references to secondary deposits of salt and the important rôle played by hot waters or thermal springs. It would seem that here the source of supply is less obscure than in Louisiana.

Africa.—Of all foreign rock salt localities none seem to show dome-structure, as developed in Louisiana, better than the conical hill, Rhang el Melah, shown on Plate LVIII, A. & B. Thirty-six kilometers southeast of this salt hill is Ain Hadjera, nearly circular in outline, 3,280 feet in diameter. (See Pl. LVIII, C.)

Here it appears the salt-forming conditions of Louisiana were repeated. Still it is of course unsafe to draw final conclusions regarding peculiar and complicated structure without careful, personal study in the field.

Algeria, the Congo region, British East Africa and German East Africa all show thermal-spring salt-deposits.

Asia.—Under Origin and Age of the Salt Range Series of India it will be noted that late views by Oldham contain suggestions of "ascending vapors or solutions."

The occurrence of masses of rock salt near the Dead Sea, a region through which a well-known extended fault line passes, is certainly very suggestive.

CHAPTER II.

NOTES ON SALT IN THE WESTERN HEMISPHERE.[1]

(Exclusive of Louisiana.)

THE UNITED STATES.

General Remarks.

Salt occurs in the United States as rock salt deposits and as natural brines. The latter are found in inland salt lakes, as underground accumulations in certain porous rocks and as surface springs. Crustal salt deposits, on or just below the surface, lie in many depressions or lake basins in the arid regions of the West. These may be considered as a phase of the inland salt lake, as most of them are covered by salt water during a part of the year. The rock salt deposits usually occur in beds interstratified with sedimentary rocks and are often closely associated with gypsum. On account of the solubility of salt the beds rarely appear at the surface, the only known cases occurring in the arid climate of some of the Western States.

The variation in the chemical composition of salt from different localities of the United States and from one Canadian locality is shown by the following analyses of rock salt and brines:

[1]Notes on U. S. and Canada, by L. Reinecke; Central and South America, by C. J. Maury.

CHEMICAL ANALYSES OF ROCK SALT.[1]

Locality	Sodium chloride	Calcium chloride	Magnesium chloride	Calcium sulphate	Magnesium sulphate	Aluminum Silicon Iron oxides	Water	Authority
Retsof, N. Y.....	98.701	.018	.055	.484	...	.743	Trace	E. Englehardt.
Pearl Creek, N. Y.....	96.885	.157	.103	.437	...	1.210	1.21	E. Englehardt.
Petite Anse, La.....	99.097	...	...	.729	.158	...	.039	O. Doremus.
Petite Anse, La.....	98.731	Trace	.013	1.192	...	.034	.030	F. Taylor.
Goderich, Ont.....	99.687	.032	.095	.090	...	.017	.079	T. Hunt.
Goderich, Ont.....	91.24	.570	.050	2.81	...	.533	...	T. Hunt.
Saltville, Va.....	99.084	Trace	...	.448	...	.470	...	C. Hayden.
Saltville, Va.....	93.05	...	...	2.400	.070	3.64	.30	T. Radcliffe.

1. E. C. Eckel, "Salt and Gypsum of Virginia," Bull. U. S. G. S. No. 213.

ANALYSES OF SOLID MATTER OF BRINES.[8]

Locality	Sodium chloride	Calcium chloride	Magnesium chloride	Calcium sulphate	Magnesium sulphate	Aluminum Silicon Iron oxides	Percent solids in brine	Specific gravity brine	Authority
Pearl Creek, N. Y.....	97.48	.26	.55	1.68	...	...	25.65	1.192	Englehardt.
Syracuse, N. Y.....	95.328	1.52	.85	2.30	...	.002	16.1	1.222	G. Cook.
East Saginaw, Mich....	81.38	.73	6.91	.53	...	.48	22.02	1.179	Douglass.
Bay City, Mich.....	91.95	3.19	2.48	2.39	...	...	16.61	...	C. Goesmann
Kanawha, W. Va.....	79.45	16.48	4.07	...	...	...	9.2	1.073	G. Cook.
Pitttsburg, Pa.....	81.27	13.93	4.80	...	...	...	2.8	1.019	G. Cook.
Colorado City, Tex....	95.864	.173	1.461	1.626	(NaHCO .867)				L. Magnenat.

8. Analyses Ito 6 from Bull. No. 213. The 7th is from Geol. Surv. Texas. Second Annual Report, 1890.

Rock salt is mined in New York, Louisiana and Kansas, and has been mined or quarried to a slight extent in California, Utah and Nevada. There are large salt deposits in western Wyoming and in Crook County west of the Black Hills; and in Arkansas rock salt has been found in Dallas and Hot Springs counties, but none of these deposits have been worked to any extent.

Salt beds are worked by the artificial brine method[3] in New York, Michigan, Ohio, Kansas, Texas and Virginia. By this method fresh water is forced down a well into the salt beds and the saturated brine is pumped up through an inner tube in the same well. At the surface the brine is treated in settling tanks to rid it of certain impurities, and is then evaporated to form the salt.

Salt beds are worked by the artificial brine method[3, 4] in New water in Massachusetts near Buzzard's Bay, and a large amount of sea salt is made in California. In Utah and to a less extent in a number of the Rocky Mountain and Pacific Coast States salt is made from salt lakes. It is manufactured from salt springs and natural brines principally in Michigan, New York and West Virginia and in Kansas, Ohio and Texas. At times salt has also been made from brines in Kentucky, Tennessee, Indiana and Missouri. In the Rocky Mountain and Pacific Coast regions salt occurs in brine springs and as crustal deposits on alkali flats. Many of these salt crusts have been worked for local use.

New York.

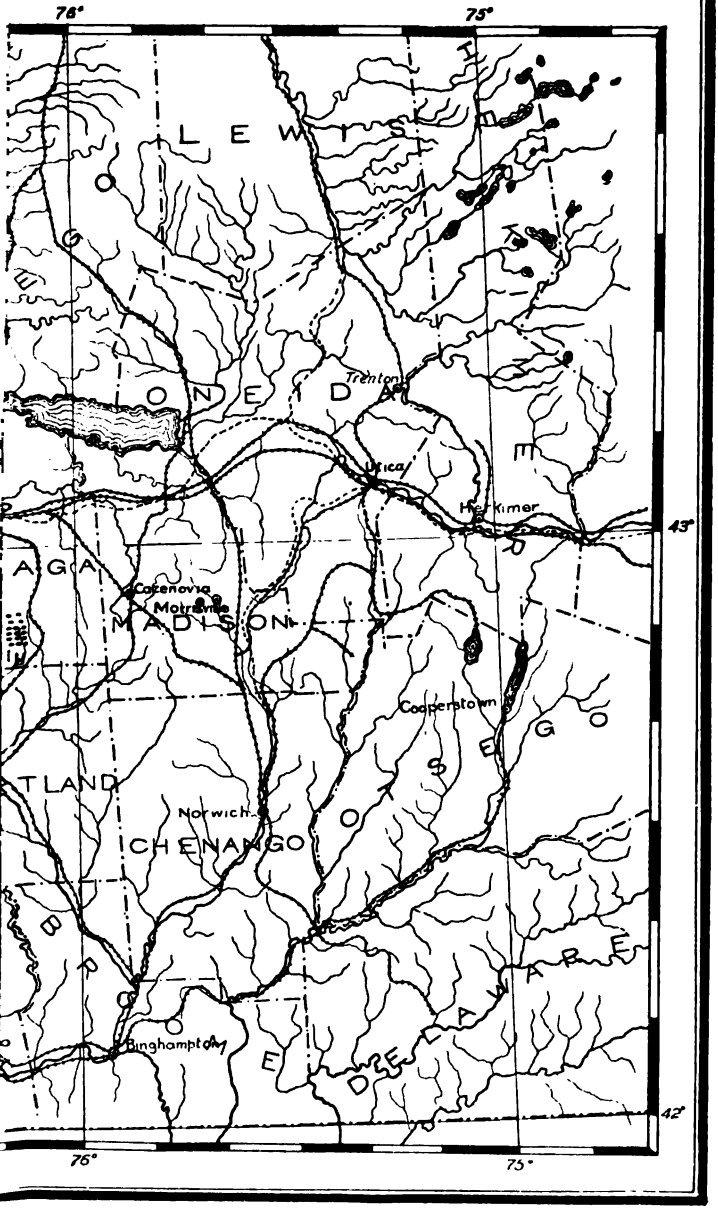
Salt occurs in New York State as natural brine and as rock salt deposits. (See Plate XXXV.)

BRINE.

Geological Occurrence.—Salt springs of varying degrees of strength, but of no present economic value, occur in rocks from the Ordovician to the Devonian.

[3]For a description of the pumping machinery see Engineering, Vol. 36, 1883, pp. 341-342, with diagrams.

[4]For a detailed account see Z. M. Kirk's article, "Evaporated Salt." Min. Resources Kansas, 1898, pp. 106 to 130, with six plates and a diagram.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The Syracuse Brines.—Brine occurs at Syracuse in the drift, filling a pre-glacial channel in the Red Salina shale.[5]

Wells, in some cases more than 300 feet deep, have been sunk into the drift and the brine is pumped from them. The brine from the shallow wells becomes weaker after being constantly pumped for a while, but the deeper wells do not seem to be thus affected. Salt is manufactured from the Syracuse brine either by artificial or solar evaporation.[6-9]

ROCK SALT.[10, 11]

Geographical Distribution.—The salt beds of New York occur in the Red Salina shales of the Silurian. These beds were formed in Professor Newberry's "Great Salt Lake," which included central and western New York, northern Pennsylvania, northeastern Ohio and southern Ontario.

In New York salt deposits nowhere outcrop at the surface. The area they underlie and their mode of occurrence has, however, been fairly well defined by the numerous wells which have been driven down to them. Thus they have been found from the Oatka Valley, in Wyoming County, east to Morrisville, Madison County, and south of this wherever wells have been put down to their horizon. But they do not extend north of the forty-third parallel. Rock salt has also been found in two or three wells in Erie County, south of Buffalo.[12]

Rock salt[13] was first discovered in New York in a boring made for oil near Vincent, Ontario County, in 1865. No attempt was made to manufacture salt from it at the time, and the discovery was not generally known. In 1878, in a well

5Rept. State Geologist, N. Y., 1896. "The Brine Springs and Salt Wells of the State of New York, and the Geology of the Salt District," by D. D. Luther.

6Wyatt, "Development of the American Chemical Industry," Engand Min. Jour., Dec. 31, 1887, p. 448 et seq.

7Geol. Surv. Ohio, vol. 6, 1888, pp. 664-667.

8Garrignes, Geol. Surv. Mich, vol. 3, Appendix B.

9Kirk, Min. Res. Kansas, 1898, pp. 106-120.

10D. D. Luther, "The Brine Wells and the Salt Springs of the State of New York and the Geology of the Salt District; report of the State Geologist, New York, 1896.

11 12 13 U. S. G. S., 21st Annual Report (1899-1900), Part VI, "Salt," by Edward W. Parker, and Mineral Resources of the United States." "The Production of Salt," by Edmund Otis Hovey; also Annual Report Supt. Onondaga Salt Springs, Jan., 1904, Hoyt H. Freeman.

drilled near Wyoming, in the Oatka Valley, a bed of rock salt 70 feet thick was struck 1,270 feet from the surface. The first works in New York State for manufacturing salt by artificial brine from a rock salt bed was put up here in 1881. A great number of wells were drilled to the salt after this, and the output from this source increased very rapidly.

Geological Occurrence.—The Salina beds in which the salt formation occurs are made of the following series: Soft shales, generally red, from 200 to 500 feet thick, which become thinner toward the east and finally disappear. These are overlain by the salt horizon, consisting of layers of pure salt interstratified with shale, limestone and gypsum, with a mixed layer of salt and rock materials at the base. They dip a little east of south at the rate of about 40′ to the mile, and the salt-bearing formation increases in thickness in the direction of dip. In the southern part of the Oatka Valley they are 100 to 138 feet thick; at Castile, 10 miles south, 190 feet; and at Ithaca, to the east and south of there, 470 feet, of which 248 feet is rock salt, occurring in seven beds. The salt deposits are overlain by 250 to 300 feet of shales and magnesian limestones containing gypsum beds in places. Above this comes the limestone of the Water Lime formation. The section of the Retsof shaft, given in Pl. XXXIX, is typical of the salt district. At the village of Wyoming the upper bed of salt is 1,270 feet from the surface; at Bliss, twenty-two miles south, 2,956, and at Ithaca, 2,244 feet.

HISTORY AND PRODUCTION.

The marketable grades of salt produced in the State include rock salt and the varieties of brine salt known as coarse solar, common fine, table, dairy, agricultural and packers' salt. In addition to the salt sold as such, a very large quantity is converted into soda products. The Solvay Process Co., at Solvay, near Syracuse, manufactures such products directly from brine that is supplied by their own wells, and the salt thus used is included in the above statistics.

Solar salt is made entirely in Onondaga County. Syracuse has long been the center of this branch of the industry, which was first started about 1789. In 1797 the Syracuse district was made a State Indian Reservation, and most of the wells are

located on the Reservation. The brine is supplied to the individual evaporating plants at a fixed charge. The brine is 17 to 20 per cent sodium chloride. It is stored in glacial gravels and has evidently been formed by circulating ground waters which have come in contact with rock salt beds.

The manufacturers of brine salt in other parts of the State obtain their supplies from wells driven into the rock salt. The Tompkins County salt is thus obtained from depths exceeding 2,000 feet.

During the past year there have been 32 companies engaged in the production of salt in the State, and these 21 were in Onondaga County. The International Salt Co. operated four plants, located at Ithaca, Myers, Watkins and Warsaw.

Rock salt was produced by the Retsof Mining Company from the Retsof shaft in Livingston County. The Sterling Salt Co. has lately opened a mine of rock salt, in the same county, at Cuylerville. The shaft was started in 1905 and was finished and equipped for hoisting in the latter part of 1906. It is bottomed at about 1,100 feet in a bed of salt that averages 21 feet thick. It has a cross section of 11 by 21 feet all over and is divided into two hoisting compartments and one ladderway. The equipment on the surface and underground is of the most approved type. The buildings, including shaft house, power houses and storage bins, are constructed of reinforced concrete. The output of the mine when under full headway will exceed 1,000 tons a day. The first shipment was made in November.

In 1906 New York produced 9,013,993 barrels of salt, valued at $2,131,650.

Michigan.

AGE AND OCCURRENCE.

The rocks outcropping in the Lower Peninsula of Michigan form parts of overlaying basin-shaped strata dipping toward a common center which lies in Gratiot or Midland counties. Rock salt or brine has been found in four different horizons in these formations.

Rock Salt: At the base of the Monroe series of Silurian age.

Brine: I. In the Berea sandstone, at the base of the Carboniferous.

II. In the Marshall sandstone of the Carboniferous.

III. In the Parma sandstone at the base of the coal measures.

ROCK SALT.

The Monroe series consists of dolomites, limestones, gypseous marls, and sandstones, with a number of thick salt beds in close succession at the base.

Geographical Distribution.—A line drawn from a point south of Muskegon passing eastward between Monroe and Wyandotte would mark the southern boundary of the rock salt deposit. It probably underlies all the Lower Peninsula[14] north of that, though it thins out toward the extreme north, and there are but few feet of salt north of Alpena and Manistee.

Thickness.[15]—Going northeast from Wyandotte the salt-bearing formation thickens, and along the St. Clair and Detroit rivers several beds over 100 feet thick occur within a vertical distance of 900 feet. The depth of the first bed of salt is 730 feet at Wyandotte, about 850 feet along the Detroit River, 1,500 feet along the St. Clair River, and 1,543 feet at the Royal Oak, where the beds attain their greatest known thickness.

At Alpena, on the shore of Thunder Bay, a layer 20 feet thick was found, 1,200 feet down. Along the Lake Michigan shore there is but one bed of salt, which is 42 feet thick at Manistee. The depth of this formation varies from 1,978 to 2,296 feet in this region. At Cheboygan, on the northern shore of the Peninsula, no salt was found at the horizon where it appears elsewhere, while at St. Ignace, across the Strait of Mackinac, a 5-foot bed of salt was struck 350 feet down.

BRINE.

Berea Sandstone Horizon.—The Berea sandstone occurs at the base of the Carboniferous. Brine has been obtained from it at Lawas and Oscoda, in Iosco County, and in Huron County, on opposite sides of Saginaw Bay. It has also been reached by deep wells at Bay City and Blackmar, Saginaw County. At the greater depths the brines contain a rather large percentage of $(Ca, Mg)\ Cl, Br)_2$.

[15]Am. Jour. Sci., 2d series, vol. 34, 1862. On the Saliferous Rocks and Salt Springs of Michigan, by A. Winchell.

[14]Geological Survey of Michigan, vol. 5, part 2; Lower Peninsula Deep Borings, by A. C. Lane.

Marshall Sandstone Horizon.—The Marshall sandstone of the Carboniferous is from 50 to 100 feet thick and underlies the Grand Rapids series of dolomites, limestones, gypsiferous sandstones and shales. Strong brine is found in the sandstone and is the principal source of supply of the wells at Bay City, Saginaw, Midland, etc., in the Saginaw Valley.

This formation is also known as the Napoleon sandstone, and with the shales immediately above it has been called the "Michigan Salt Group."

Seventeen thousand square miles, approximately, are underlaid by this horizon, embracing the central part of the Peninsula, and containing 19 counties and at least half of 16 others.

Parma Sandstone Horizon.—The Parma sandstone occurs at the base of the Saginaw Coal Measures. A rather weak brine is obtained from it at Bay City and other places.

No rock salt has been found in any of the three last mentioned horizons. The brine is therefore either the original brine in which sandstones were deposited or brine leached from the rock salt deposit of the Monroe.

METHODS OF WORKING.[16]

The rock salt deposits have, up to the present, been worked entirely by the artificial brine method mentioned above, though attempts have been made to sink shafts to the deposit and mine the salt directly. These have not been successful on account of the presence of water containing large amounts of hydrogen sulphides some distance above the salt. A new shaft was begun in February, 1905, not far from Detroit, in which the difficulty has been overcome, and which it is hoped will successfully reach the salt bed.

HISTORY AND STATISTICS.[17-19]

The first brine well in Michigan was put down at East Saginaw in 1859. Four thousand barrels were produced in 1860. In 1906 the output was 1,391,522 short tons, valued at $2,018,760.

[16] Eng. and Min. Jour., Nov. 25, 1905.

[17] U. S. G. S., 18th An. Rept., 1896-1897, part 5. Mineral Resources of the United States, 1896. "Salt," by Edward W. Parker.

[18] U. S. G. S., 21st An. Rept., 1899-1909, part 6, Mineral Resources of the United States, 1899. "Salt," by Edward W. Parker.

[19] U. S. G. S., Mineral Resources of the United States, 1903, 1904 and 1906.

Ohio.[80]

Salt is manufactured in Ohio from natural brines in the southeastern part of the State, and from the artificial brines derived from rock-salt beds to the northeast.

NATURAL BRINES.

Salt was first made from brine wells in the Scioto licks, Jackson County, in 1798.

Wells were first bored in the Muskingum Valley in 1817. It is said that from 60,000 to 80,000 barrels were produced there in 1833.

Salt has been made in Morgan County since 1825. One plant remains at Durant, in the northern part of the county. The brine here comes from two wells about 670 feet deep. The mouths of the wells are about 50 feet above the middle Kittanning coal. Meigs County is the most important producer of southeastern Ohio. During the "sixties" there were at one time 13 furnaces in operation. At present five works in the neighborhood of Pomeroy are all that remain. These receive their chief revenue from the manufacture of bromine and calcium chloride from the mother liquor after the salt is precipitated.

The strata in this vicinity dip to the southeast. The brine increases in strength in the direction of the dip. In a given well the deeper brine appears to be the stronger. In a well at Pomeroy which went through the Berea grit and was 1,580 feet deep, brine was found at four horizons—300, 710, 980 and 1,550 feet—registering 6°, 9°, 9° and 16° Beaumé, respectively. The lowest brine was in the Berea grit of the Carboniferous. Though this brine is the strongest, there is but little of it, and most of the pumping is done from the horizon above.

Analysis.—An analysis of the solid contents of the brine from a well at Pomeroy is given below:

Sodium chloride	80.134
Calcium chloride	13.633
Magnesium chloride	5.314
Magnesium bromide	.147

[80]The most complete account of the salt of Ohio is in "Salt Deposits and the Salt Industry in Ohio," J. A. Bownocker, Geol. Surv. of Ohio, 4th series, Bull. No. 8, five plates and a map.

Sodium iodide	.004
Silica	.011
Iron and aluminum oxides	.108
Potassium chloride	.244
Strontium	...
Barium chloride	.326

Specific gravity, 1.075.

The absence of sulphates in these brines is accounted for by the presence of barium. The brine is probably ocean water, which was enclosed in the rocks when they were deposited.

ROCK SALT.

Extent.—Rock salt was discovered in 1886 in a well drilled for oil at Newberg, near Cleveland, and since then explorations have shown a profitable field to extend from Wayne and Medina counties north and east through the State. Salt is worked at Newberg, Cleveland, Kenmore, Wadsworth and Akron.

Occurrence.—The salt occurs in beds interstratified with limestones and some shales, of Salina age. The salt beds vary individually from 2-7 feet in thickness and aggregate from 7-8 feet. The depth of the upper beds of salt ranges from 1.790-1,990 feet at Cleveland to over 2,500 feet at Rittman, Wayne County; 2,774 feet at Barbertown, Summit County, and 3,239 feet at Cortland, Turnbull County.

Methods of Working.—The brines in southeastern Ohio were formerly evaporated in iron kettles, but open pans are now used in the few remaining works.

In the northern part of the State the rock salt is worked by the artificial brine method and the brine is evaporated in grainers and vacuum pans.

PRODUCTION.[21-24]

In 1880 Ohio produced 530,000 barrels, all of which came from the southwestern part of the State. A few years after the

21. For an account of the methods of making bromine and calcium chlorides, see E. W. Parker, "Salt," U. S. G. S., 18th An. Rept., Part V, 1896.

22U. S. G. S., 21st An. Rept., part 6, 1899-1900. Mineral Resources of the United States; "Salt," by Edward W. Parker.

23U. S. G. S., Mineral Resources for the United States for 1903, 1904 and 1906.

24Geological Survey of Ohio, Economic Geology, vol. 6, 1888.

salt beds in the northeast became important. Ohio is now the third State in rank of salt production, the output in 1906 being 453,150 short tons.

Kansas and Oklahoma.

AGE AND OCCURRENCE.

Salt occurs in Kansas as brine in the Carboniferous, as rock salt interbedded with shales of Permian age, and as surface deposits in salt marshes or plains, derived from brine in Cretaceous shales.

CARBONIFEROUS BRINE.

Many salt springs are found through the Carboniferous area of the State. Though salt has been made from several of them at times, the only ones of importance are those at Solomon City, in Dickinson County, which have been worked since 1867. In 1898 the works there had a capacity of 4,000 barrels per annum.

SALT MARSHES OR PLAINS [25]

The salt marshes lie in a belt extending in a direction west of south from Republic County through Jewell, Cloud, Mitchell, Lincoln and Stafford counties and across the State line into Oklahoma.

Salt marshes are also found northwest of Gueda Springs, in Cowley and Sumner counties.

The typical salt plane lies in a valley bottom bounded by shale bluffs. The surface is level and is wholly or partly covered by a salt crust in the dry season and often contains numerous salt springs. The largest one in the State is about seven miles long and from one-quarter to one mile wide.

Salt was manufactured in small quantities at the Tuthill marsh, and also in Lincoln and Stafford counties, in the seventies, and supplied a local demand.

The Oklahoma salt plains resemble those in Kansas. The largest, on the Salt Fork of the Arkansas, is 14 miles long and 8 miles at its widest point. The most important economically is that on the Cimarron River, near the junction of Buffalo Creek. A good deal of salt was gathered there in former times

[25] The Oklahoma Salt Plains, by C. N. Gould, Trans. of the Kansas Acad. of Sci., Vol. XVII, 1899-1900.

and taken to various points in Indian Territory and Kansas, and it is yet a source of supply to ranchmen in the neighborhood.

Geological Occurrence.—The Gueda marshes derive their brine from the rock salt horizon at the top of the Permo-Carboniferous. The Oklahoma plains apparently have their brine reservoirs in the same horizon or in the red shales (Harper formation) immediately above. These red beds are also the source of brine of the Stafford County marshes.

The brine supplying the other salt marshes in Kansas comes from the upper group of the Dakota series of the Cretaceous.[26] The salt horizon consists of a bed of saliferous shales, 15 to 30 feet thick. It rests upon a thin bed of lignite and underlies 10 to 20 feet of gypsiferous shales. The latter shales are capped by a thin band of sandstone which divides the Dakota from the Benton above.

ROCK SALT.[27-29]

Geographical Distribution.—The area underlaid by beds of rock salt in Kansas has been only partially determined by wells and shafts sunk to them. The eastern boundary is the best known and extends from a point between Wellington and Gueda Springs, in Sumner County, north and slightly east through Sedgwick, Harper, Reno and Macpherson counties and up along the western edge of Saline County. From south to north it is known to extend from Anthony, in Harper County, up to Ellsworth County, and its known westerly limits lie in Barton, Stafford and Pratt counties. The beds probably underlie a large tract of country north, west and south of the area indicated, though not perhaps in all cases at a depth which would make their working practicable.

Geological Occurrence.—The salt deposit occurs in beds interstratified with grey and blue shales of the Permian system. The

[26]The UpperCretaceous of Kansas, by W. N. Logan, the Univ. Geol. Surv. of Kansas, Vol. II, 1896.

[27]"Salt," by Erasmus Haworth and Z. M. Kirk, the Univ. Geol. Surv. of Kansas, Annual Bulletin of Resources for 1898.

[28]"Geology of Kansas Salt," by Robert Hay, Kansas State Board of Agr., 7th Bien. Rept., Vol. XII, 1889-90; Kansas Acad. of Sci., Vol. XII, 1889-90, Kansas Salt Marches.

[29]Notes on last two by Robert Hay.

total thickness of the salt-containing horizon varies from 553 feet at Anthony, in the south, to 250 feet at Kanapolis, on the northern edge of the field, and from 50 feet at Wellington, near the southern boundary, to 415 feet at Kingman.

The thickest layer of salt is given as 275 feet in a well at Anthony. There is a layer 195 feet thick in a well at Kanopolis and 270 feet at Wilson, a little farther north.

At Lyons, where a detailed and accurate section was kept in sinking a shaft, there are twelve beds of clear salt, the thickest of which is 17 feet.

The salt horizon rests upon the limestone and shale of the Marion formation and is overlain by blue or grey shale from 70 to 250 feet thick, of the Wellington formation. The Wellington is overlain by red shales containing gypsum and limestone in places. The blue and red shales are often interbedded, though the salt is in every case overlaid by blue shale. The red shales are the highest Permian beds in this region.

Methods of Working.—Shafts have been sunk to the salt at Lyons, Kanapolis and Kingman. Elsewhere in Kansas the rock salt is worked by the artificial brine method. In connection with the evaporation of brine some of the companies have within the last few years used a pan made of Portland cement instead of iron. The brine is heated by steam pipes passing through the pan. The wells at Hutchinson produce a very large proportion of the State output.

HISTORY AND STATISTICS.

Rock salt was discovered in wells put down at Hutchinson, Lyons, Kingman, Kanapolis and other towns in the autumn of 1887 and 1888. In the latter year the output was 155,000 barrels.

Kansas in 1906 produced 307,837 short tons and ranked fourth in value of salt production.

In Oklahoma salt is produced chiefly near Ferguson, Blaine County.

California.

OCCURRENCE.

Brine in springs or salt marshes occurs in a great many localities throughout the State. Salt occurs as crystal surface

deposits from these marshes or playa lakes. Rock salt occurs in a few deposits in the earlier marine strata. By far the largest amount of salt produced, however, is manufactured from ocean water by solar evaporation.

BRINE.

In Inyo, San Bernardino, and other counties in the Great Basin area, almost every spring and stream is salty. Brine springs are numerous along the Salinas River in San Luis Obispo County. There are salt springs in Lake County, Santa Clara County and many others.

SALT LAKES.

Most of the so-called salt lakes contain water only during the rainy season. At other times they are covered with a crust of salt often several inches thick, deposited by the evaporation of the water. There are many such depressions in the desert portion of the Great Basin area from which salt is collected merely by scraping the crust.

Salton Sea.[30]—A few years ago the most noted of these lakes was Salton Sea, in Riverside County. This is an inland basin, 27 miles long and from 3½ to 9 miles wide. At its lowest point it is 280 feet below sea level and receives the drainage of from eight to nine thousand square miles of desert country. Brine from numerous salt springs in the adjacent hills flows into the depression and from 10 to 29 inches of salt a day was deposited there in the dry season. The salt is broken up by plows, thrown into piles, taken to the mill and crushed to the required sizes. Five hundred thousand short tons were produced annually.

About a year ago this basin was flooded by the diversion of the Colorado River into it, caused by a mismanaged attempt to divert the river from its natural channel. The basin is now a vast lake, whose water level was rising at the rate of one inch per day (in January, 1906).

From two to three hundred short tons of salt per year are produced from the Cameron Lake, in Kern County. Probably from 5,000 to 10,000 tons of salt a year are produced by playas, salt lakes and rock salt deposits in Inyo County.

[30] Nat. Geograph. Mag., vol. 17, No. 1, p. 61.

ROCK SALT.[31]

Occurrence.—Many playas are underlaid by beds of rock salt near the surface, interstratified with clays or sands. They are evidently of the same character as the crust now being formed on the surface, and of recent origin. Rock salt also occurs in beds interstratified with sands of the "Niter Beds" of Eocene age.

Two beds of salt from 2 inches to 8 feet thick occur at Danby, San Bernardino County. They are separated by a thick seam of clay and overlaid by sand and dust from a few inches to two feet thick. Some 3,000 or 5,000 tons were mined there in 1896.

Salt in Niter Deposits.—On the north flank of the Avawatz Mountains, south of Saratoga Springs, in a canyon near the Daggett Death Valley road, a seam of salt from 12 to 16 feet thick crops out for 1,500 feet. It runs 95% NaCl, and is over- and underlaid by a bed of mixed sand and salt for a thickness of 25 feet. These beds are overlaid by beds of gypsum, sandstone, and layers of sulphates, carbonates, and nitrates of soda. The deposit was worked to some extent about 25 years ago.

Rock salt has been found at the head of the Salinas River, in San Luis Obispo County.

SEA SALT.

Salt has been manufactured by solar evaporation from sea water at the south end of San Diego Bay and at Ocean Side, San Diego County. The principal works, however, are on the south and east ends of San Francisco Bay, Alameda County. In 1901, 90% of the total production of the State came from this county.

PRODUCTION.[32]

California ranks sixth as a salt-producing State, with an output in 1906 of 112,950 short tons.

[31] U. S. G. S., 18th An. Rept., part 5, Mineral Resources of the United States for 1896. "Salt," by E. W. Parker.

[32] California State Mining Bureau Bulletin, No. 24, 1902; Min. Res. of the U. S. for 1906.

West Virginia.

OCCURRENCE AND AGE.[33, 34]

Salt is made in this State from brine wells along the Kanawha River and in Mason County on the Ohio River.

The Kanawha brines are found in the sandstones and conglomerates of the Pottsville series of the Carboniferous. It lies at from 600 to 1,000 feet below the surface in the salt region. The wells in Mason County may be considered to get their brine from the same horizon as those in the Pomeroy district of Ohio, across the Ohio River from them. The brine obtained from the latter comes, according to Dr. Edward Orton, from the Logan series of the Sub-Carboniferous. This formation consists of conglomerates, sandstones, and shales, lying about 25 feet below the Pottsville.

HISTORY AND STATISTICS.[35, 36]

The first salt furnace in West Virginia was erected in 1797 at the Buffalo lick near the mouth of Campbell Creek, in the Kanawha Valley. A plant at Malden is the only one now producing salt in the Kanawha Valley. Brine is obtained only from Hartford, Mason County. This and the Malden plant together produced, in 1906, 200,055 barrels of salt.

Texas.[37-40]

The many types of brine occurrence are well represented in this State, and in a few localities well-developed beds of rock salt have been discovered and worked.

33. "Charleston Folio, W. Va.," by M. R. Campbell; U. S. G. S. Geol. Atlas of the U. S., Folio No. 72, 1901.

34. "Geological Survey of Ohio," Economic Geology, Vol. VI, Edward Orton, 1888.

35. Min. Res. of U. S. for 1896 and 1906.

36. "Observations on the Saliferous Rock Formation in the Valley of the Ohio," S. P. Hildreth, Am. J. S., Vol. 24, 1833.

37. Second and Third Annual Reports of the Geological Survey of Texas, E. T. Dumble, 1890.

38. Second Report of Progress, Geological Survey of Texas, E. T. Dumble, 1891.

39. "The Minerals and Mineral Localities of Texas," F. W. Simonds, Bulletin of the University of Texas, No. 18, 1902.

40. "Salt, Gypsum and Petroleum in Trans-Pecos Texas," by G. B. Richardson, in U. S. G. S. Bulletin No. 260; Min. Res. of the U. S. for 1906.

SALT LAKES.

A good deal of salt has been made from the numerous lagoons and salt lakes along the southern coast. A dry "salt lake" of the type common in southeastern California occurs in the salt basin of the Trans-Pecos region in western Texas. It is about 45 acres in extent and it is said to have been worked since early times by the Mexicans. At present large quantities are sold to ranchmen and the salt is sometimes hauled over wagon roads for more than 100 miles.

SALT STREAMS.

Many of the streams originating in the Permian clays of northwestern Texas are salty, the Salt Fork of the Brazos and the Salt Fork of the Red River more markedly so. Below its confluence with the Double Mountain Fork of the Brazos, the Salt Fork is, at low water, almost brine. Fairly thick crusts of salt are left on the banks of Croton Creek a few miles above where is joins the Salt Fork of the Brazos, and a small quantity is occasionally hauled from there by neighboring stockmen.

BRINE.

Brine has been obtained from the wells in the Carboniferous and salt was made from brine in this horizon at Graham, in Young County. There is a brine horizon in the Paluxy Sand of the Cretaceous.

ROCK SALT.

Occurrence and Age.—Rock salt has been found at Colorado City, Mitchell County; at Grand Saline, Van Zandt County, and near Palestine, Anderson County.

The salt at Colorado City is presumably of Permian age. The first bed is 850 feet from the surface and there is about 140 feet of salt within the next 250 feet. In 1890, 750 tons per month were manufactured from four wells.

Grand Saline.—The way the rock salt occurs at Grand Saline is shown in the following sections. Both are near the western side of the saline:

Lone Star Well.

Sand, gravel, clay and shale	178 ft.
Hard sand, rock	6
Shale with pyrites	4

Blue limestone with streaks of sand and gray limestone.	42
Gypsum	5
Rock salt	124
Total	359 ft.

Richardson Well.

Sand, clay, and gravel, with broken limestone near bottom	83 ft.
Hard gray limestone	3
Clay, shale, and sandstone with pyrites	77
Blue and gray limestone	28½
Quicksand	2½
Alternate salt and limestone	18
Rock salt	300
Blue and black sand	8
Total	530 ft

PRODUCTION.

Texas produced 50,502 short tons of salt in 1906. This was all obtained from brine by solar or grainer process.

Utah.

Salt is manufactured on the shores of Great Salt Lake by solar evaporation from the lake water, and brine is also obtained at Nephi City, Juab County.

Rock salt occurs at Nephi, where small quantities have been mined, near Gunnison, Sanpete County, and in Sevier and Salt Lake counties.[41] The deposits are crustal. That in the dried bed of Sevier Lake is about 8 miles long, 5 wide and 5 inches thick and is composed of a variety of salts, sodium sulphate being more abundant in the center and sodium chloride toward the margin of the deposit.

GREAT SALT LAKE.

The brine as taken from Salt Lake is highly concentrated, carrying 20 per cent of saline matter. On account of this degree of concentration it is practically free from gypsum and calcium carbonate.

41. Min. Res. of the U. S. for 1906.

Analyses.—The following table of analyses taken from an article on "The Salt Industry in Utah and California" by E. C. Eckel of the U. S. G. S., shows the variation in composition and density of the brine in different years:

Year——	1850	1869	1873	1885	1889
Analyst——	L. D. Gale	O. D. Allen	H. Bassett	J. E. Talmage	
Sodium chloride.....	20.20	11.86	8.85	13.59	15.74
Potassium chloride....	....	....	1.89	....	....
Magnesium chloride...	.25	1.49	1.19	1.13	2.01
Sodium sulphate.....	1.83	.93	1.09	1.42	1.05
Potassium sulphate....	....	.53	....	.43	.47
Sodium sulphate.....	....	.09	.20	.15	.28
Total solid contents...	22.42	14.82	13.67	16.72	19.55
Density	1.17	1.111	1.102	1.122	1.157

The following are analyses of commercial salt made from brine of the Great Salt Lake:

Oxide of silicon.....	.214	.472	.201	.102	.007
Sodium chloride.....	98.101	98.300	98.121	98.407	99.927
Calcium chloride....	.322	.345	.311	.371	Tr.
Magnesium chloride..	...	...	...	...	Tr.
Calcium sulphate....	.364	.680	.422	.650	.058
Magnesium sulphate..	.021	.042	.022	.030	...
Water	.952	.158	.911	.442	.008

Methods of Working.[42]—The methods used at Salt Lake City are in principle the same as those used in the solar evaporation plants of San Francisco Bay in California.

HISTORY AND STATISTICS.[43]

The Mormons began collecting salt from pools along the shores of Great Salt Lake in 1848. Westerly winds filled these pools or depressions along the shore with lake water, which evaporated in the dry season, leaving crusts of salt on the bottom.

42. A full account of the method of salt harvesting and milling in use at Salt Lake is given in U. S. G. S. Bull. 213; "The Salt Industry in Utah and California," by E. C. Eckel, 1903.

43. For accounts of the history of salt making in Utah, see U. S. G. S. 19th Ann. Rept., Part VI, 1898, p. 608.

The first artificial ponds for the evaporation of the lake water were made about 1860. The utilization of the chlorination process for the reduction of silver ores about this time gave the industry a great stimulus. The Alice mine at Butte, Montana, was the first to use salt for that purpose, and it was sent there on pack mules at a cost of $200 per ton.

In 1906 Utah produced 36,710 short tons.

Virginia.

Although rock salt is found at several localities in the State, it is only commercially important near Saltville, Smyth County.

SALTVILLE.

Saltville lies in the valley of the North Fork of the Holston River. A fault with a throw of about 8,000 feet passes through the town in a direction 60° east of north and is continued up the valley. The salt occurs on the northwestern side of the fault only, in a belt between it and the foothills of the valley.

Occurrence and Age.—The salt occurs interbedded with shales and shaly limestones of the lower member of the Greenbrier limestone of the Carboniferous.

Thickness of the Salt.—A shaft sunk in 1840 indicated a total thickness of 166 feet of salt with some interbedded shales. The top of the salt is 220 feet from the surface. Prof. H. D. Rogers,[44] in an article written in 1854, states that one well passed through 300 feet of salt with a little clay. A later estimate gives the thickness of the salt and included shales as 175 feet.

The shales above the salt bed are very much weathered and are charged with a strong brine.

Analyses.—The following is an analysis of rock salt found in the shaft referred to above:

Sodium chloride	99.084%
Calcium chloride	Trace
Calcium sulphate	.446
Iron and aluminum oxides	.470

44. "Report on the Salt and Gypsum of the Holston River, Virginia," H. D. Rogers, 1854; reviewed in Am. Jour. Sci., Series II, Vol. 18, p. 273.

Brine from a depth of 193 feet shows the following composition:

In 1,000 grains of brine.

Sodium chloride	240.52
Calcium sulphate	5.35
Calcium sulphate	.446
Iron and aluminum oxides	Trace

HISTORY AND STATISTICS.[45, 46]

Salt was gathered from the lick above the deposit by Indians before the advent of the whites.

Rock salt was discovered in 1840. There has been no attempt at direct mining, the salt being manufactured from brine.

In 1854 there were five brine-producing wells in the Holston Valley and during the Civil War 10,000 bushels were produced per day. The industry has since declined and at present the brine is used only for chemical purposes.

Pennsylvania.[47-50]

OCCURRENCE.

At Saltsburg, on the Conemaugh River, there was a considerable output of salt at one time, derived from a weak brine in the Pocono sandstone of the Sub-Carboniferous.

In Clearfield County, salt water was found in a well at a depth of 548 feet.

PRODUCTION.

In 1884 there were 16 salt-making establishments in the State. In 1892, the first published report gave an output of 25,571 barrels, which is probably below the actual production In 1893 the output was 280,343 barrels, but in 1898, the last year in which the production for Pennsylvania was published separately, it had decreased to 154,287 barrels.

45. "Salt and Gypsum Deposits of Southwestern Virginia," by Edwin C. Eckel, U. S. G. S. Bulletin No. 213. See also:

46. "Notes on the Holston (Virginia) Salt and Gypsum," by Wyndham Robertson, in the Virginias, Vol. 3, 1882.

47. U. S. G. S. Atlas of the U. S., Folio No. 82.

48. "Some Recent Discoveries of Rock Salt in Western New York," J. S. Newberry, N. Y. Acad. Sci. Trans., Vol .4.

49. "A Salt Boring in Clearfield County, Pa.," J. M. Hale, Am. Phil. Soc. Proc., Vol. 9.

50. U. S. G. S. 21st Ann. Rept., 1899-1900, "Salt," by E. W. Parker.

Nevada.[51 52]

ROCK SALT.

A thick deposit of rock salt outcrops in a bluff facing the stream in the valley of the Virgin River, a few miles north of the Colorado River, in the southeast portion of the State. Twenty miles up the river on the west side of the stream there is a similar deposit of less extent.

The salt contains about 90% sodium chloride and was worked to some extent in an open quarry in 1883.

BRINE AND SALT CRUSTS.

Deposits of salt crusts in alkali flats occur all over the State. Enough salt could be harvested in most of the large counties to supply the local demand.

PRODUCTION.

In the eighties, most of the salt output was used in the silver mills, but since then the production of salt has declined and in 1906 only 11,249 barrels were produced in Nevada. The salt is won at present only in Washoe and Churchill counties and is obtained from brine by solar evaporation.

IDAHO.

Salt deposits occur in Idaho in Bannock County, near the Wyoming line. The salt is won by the open-pan process, with heat applied directly underneath.

In 1906 Idaho produced 1,574 barrels.

NEW MEXICO.

Salt is manufactured in Torrance County, New Mexico, by the solar evaporation of brine.

Production of Salt in the United States.

In early colonial times sea salt was made at a few places on the eastern coast of the United States in primitive ways. It is said that the possibility of making solar salt in this climate was first suggested by finding salt crystals in empty mussel shells on the beach. The first evaporating shed was put up at Cape Charles, Va., in 1820, but the colonists depended largely on salt imported from England. Shortly before the Revolution the price of English salt rose so enormously that many families

51. Min. Res. of the U. S., 1882 and 1906.
52. U. S. G. S. 20th Ann. Rep., Part VI, 1898-1899.

began to make their own salt, which, as a rule, contained many impurities. Later a better grade of salt was made from brines inland which had long been used by the Indians.

During the past quarter century the increase in the production of salt in the United States has been enormous. In 22 years it quadrupled. During the past two years the most striking feature has been the increase in the production of brine due to the growth of chemical industries during these years.

The United States leads the world in the production of salt. In 1906 the total output was 3,944,133 short tons.

Importation and Exportation.[55-57]

According to the present tariff law, which went into effect in 1898, the duty on foreign salt entering the United States is 8 cents per hundred pounds for salt in bulk and 12 cents per 100 pounds for salt in bags or barrels. The duty on imported "packers" salt may, under certain conditions, be remitted.

In 1906 the total quantity of salt imported into the United States was 349,262,660 pounds, valued at $508,862. The imports are chiefly from the United Kingdom, the West Indies, Italy and Canada. The imports from the West Indies declined from 1903 to 1905, but rose again in 1906 and amounted in that year to nearly 93,000,000 pounds.

The United States in 1906 imported 67,976,581 pounds of salt, valued at $274,627. The export trade has been gradually rising during the past five years. The marked feature in 1906 was the increased exportation to Asiatic Russia and Cuba.

The average net value of salt in the United States in 1906 was 23 cents per barrel, or $1.69 per short ton.

Canada.

According to the latest returns, all the salt produced in Canada comes from the Goderich salt field (see Plate XL) in Ontario, where it is manufactured from an underground bed

55. Imports of Merchandise, Dept. Commerce and Labor, No. 3, 1902-1906, pp. 310-311.

56. Monthly Summary of Commerce and Finance of the U. S., Nov., 1906, p. 935.

57. Min. Res. in the U. S. for 1906, advance chapter, "Production of Salt," by A. T. Coons.

GODERICH SALT FIELD AND SURROUNDINGS, ONTARIO, CANADA

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of rock salt by the artificial brine process. Small quantities have at times been made from brine springs in other localites.

Brine Springs.[58]

New Brunswick.

Near Sussex, in King's County, salt was made from brine springs for more than 100 years. The production between 1887 and 1897 averaged 150 barrels per year. The springs occur in Lower Carboniferous strata. Similar springs occur at Salt Springs, King's County, and on the Tobique River, Victoria County.

Nova Scotia.

At Antigonish, Nova Scotia, salt was formerly made from brine springs in Carboniferous strata. Some was also manufactured at West River, in Pictou County.

The specific gravity of the brine in New Brunswick and Nova Scotia is seldom more than 7% Baumé.

Manitoba.[59]

In Manitoba salt springs occur on the shores of Lake Manitoba and Lake Winnipegoosis. On the south end of the latter lake salt was made from the brine for a long time. One hundred barrels were produced here in 1874 and between 30 and 40 in 1896. Salt was formerly made from a brine spring in the Red River Valley, 13 miles below Winnipeg, and a strong brine occurs at White Mud Creek. The two latter are in a belt underlain by Devonian strata. Lenses and crystal masses of salt are said to occur in a porous dolomite in the Devonian.

Northwest Territory.

Redberry Lake, 35 miles west of Carlton, on the Saskatchewan River, is saline. Salt springs with strong brine occur on the Clearwater or little Athabasca River. Twenty miles up the Salt River, which enters the Great Slave Lake 100 miles below Lake Chippewyan, considerable amounts of salt have been collected in a plain from a crustal deposit formed by brine springs. Another large deposit is said to occur on the Portage midway between Great Slave and Great Bear lakes. On Great

58. See volumes of the Canadian Geological Survey, Reports of Progress and Annual Reports from 1863 and later.

59. Manitoba Hist. and Sci. Society, Trans., No. 27, 1886-7, Footsteps of Time in the Red River Valley."

Bear Lake River, just below the rapids, a small stream enters from the south. The Indians formerly gathered salt from a crustal deposit near its source.

British Columbia.

In British Columbia there is a salt pond near Lake Temapho and a salt spring on the northern end of Admiral's Island off the east coast of Vancouver.

Rock Salt.

Goderich Field.[60-63]

The only known deposit of rock salt in Canada occurs on the east and south of Lake Huron. The beds of salt are similar in character and of the same geological horizon as those in New York.

EXTENT.

The salt is worked within a strip of country about 40 miles wide along the eastern and southern shores of the lake in the Counties of Essex, Lambton, Middlesex, Huron, and Bruce.

The two localities in Perth County mentioned in the statistics[63] published in 1886 are indicated on the map, Pl. XL. In 1900 there were no producing wells in Perth County.[64] Borings have proved the absence of salt beds at Inverhuron, nine miles north of Kincardine and Leeswater, 20 miles south and east of the same place; also at Mitchell, 11 miles southeast of Seaforth, thus roughly establishing the northern and eastern limits of the field. To the south it extends for about 150 miles into Essex County.

OCCURRENCE OF THE SALT.

The salt occurs interstratified with soft marls, dolomite and anhydrate, which have been referred to the Salina group of the Upper Silurian.

60. "The Goderich Salt Region," by T. S. Hunt, 1869, Canadian Geol. Surv., Rept. of Progress, 1866-70, pp. 211-244.

61. Can. Geol. Surv., Rept. of Progress, 1876-7, pp. 221-243, with section. The latter report is also published in the Transactions of the Am. Inst. Min. Eng., Vol. 5, pp. 538-560.

62. "The Salt Deposits of Western Ontario," J. Gibson, Am. Jour. Sci., Series III, Vol. 5, pp. 362-369.

63. "The Manhattan Salt Mine at Goderich, Ontario," O. J. Heinrich, Am. Inst. Min. Eng. Trans., Vol. 6, pp. 125-144.

64. Can. Geol. Surv., Rept. of Progress, 1874-5, p. 298; Ann. Rept., new series, Vol. XIII, 1900, pp. 128-130 S: Ann. Rept., new series, Vol. II, 1886, pp. 63-72 S.

SECTION OF WELL NEAR GODERICH, ONTARIO

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In a test boring[65] put down on the north bank of the Maitland River near Goderich in 1876, six beds of salt with a total thickness of 126 feet were passed through within 388 feet, the boring ending in soft marls with dolomite and anhydrate 132 feet beneath the last bed of salt (see Pl. XLI). Above the salt come 121 feet of marls, 243 feet of dolomite with gypsum, 276 feet of coralline and cherty limestone with beds of dolomite and 278 feet of dolomite with thin layers of limestone. The latter dolomite formation has been correlated with beds of the Waterlime Group of Upper Silurian Age on the shores of Lake Erie. The dolomite is covered by 78 feet of drift deposit. The Salina in this region rests upon the Guelph Group, an upper continuation of the Niagara limestone.

DEPTH OF UPPER BED.

At Kincardine the upper bed of salt is 883 feet from the surface; at Wingham, 1,090 feet; in the neighborhood of Goedrich, from 967 to 997 feet; at Seaforth, 1,035 feet; at Clinton, 1,116 feet; at Exeter, 1,194 feet, and 1,200 feet at Warwick, Lambton County. At Windsor, in Essex County, 389 feet of salt was found in a well 1,673 feet deep, so that the first bed could not have been much below 1,200 feet. These figures indicate a dip to the east and south.

COMPOSITION OF THE SALT.

The second bed of rock salt in the boring above referred to is suitable for mining throughout almost its entire thickness. An analysis is given below of a representative sample taken from a 10-foot layer of particularly pure salt in this bed:

Sodium chloride	99.687
Calcium chloride	.032
Magnesium chloride	.095
Calcium sulphate	.090
Insoluble in water	.017
Moisture	.079
	100.00

The sodium of chloride was found by difference.

65. Can. Geol. Surv., Rept. of Progress, 1876-7, pp. 211-244.

It is estimated that this band of salt 10 feet thick would yield 22,200 tons per acre, allowing for waste in mining.

METHODS OF WORKING.[66]

The salt has been worked entirely by the artificial brine process described above. (See "The Salt Industry of the United States.")

An attempt was made to sink a shaft at Goderich but was abandoned on account of an influx of water. There were 23 salt-making concerns in this field in 1903.

HISTORY AND PRODUCTION.[67] [68]

Rock salt was first discovered in this region in a well put down for oil at Goderich in 1866. Four more were put down at Goderich in 1868, the five producing 375 barrels per day at the end of the year.

In 1905 Canada produced 67,340 short tons of salt, valued at $320,858.

Mexico.

General Occurrence.

On the high plateau of Mexico there are salt deposits in lake beds which are very similar to the salines of the Argentine. Brine springs, saliferous earths and rock salt deposits also occur. But the greater part of the salt produced in Mexico is made in sea salines, as that from the brines, salt lakes and saliferous earths is impure and is used almost entirely for the amalgamation of ores.

SALT LAKES.

The salt lakes of Mexico vary greatly in the amount and kinds of salts[64] that they contain, but in general they form a deposit known as *tequezquite*,[65] which is a corruption of the Mexican word *tequixquitel*, "something like a stone." It is a mixture of salts, chiefly carbonate of soda and sodium chloride. When sodium chloride predominates, the deposit is called *sal-tierra*, or earthy salt, which is used in the reduction of lead and silver ores.

66. Engineering and Mining Journal, July 24, 1886, p. 55.
67. Geol. Surv., Canada, Ann. Rept., new series, Vols. II, XIII; Report of Progress, 1874-75; Min. Res. of the United States for 1906.
68. Das Salz, Von Buschman, Leipzig, 1906.
69. Bull. Soc. Geol. de France, Vol. 22, 1866, pp. 465, 472.
70. Villada, El Tequezquite, 1870.

Every year saltierra is harvested from Lake Texoco, a large, shallow lake near the City of Mexico. Salt is also obtained from the lagunilla de Salinas, north of the city, near Tula, but it contains sulphates of sodium and magnesium, as well as sodium chloride.

There are also a number of lakes from which salt is harvested in the States of San Luis Potosi, Zacatecas and Durango. The most important salines in these states are those of San Antonio, Santa Clara, Doncella and Penon Blanco.

.In the State of Coahuila there are salt deposits in the beds of ancient lakes, which have been exploited since 1899, when the industry was encouraged by cheap freights on the nearby railway.

BRINES.

Brine springs[71] flow from the Upper and Lower Cretaceous and from Tertiary beds. The Lower Cretaceous brines are in the State of Puebla; the Upper Cretaceous in the State of Coahuila, and the Tertiary in the State of Tamaulipas

Saliferous Deposits.

In the highlands of the State of Oaxaca about 100 tons of a coarse. impure salt is made from saliferous earths and is called Sal de boya. It is used only for cattle.

Saliferous deposits are also found in the State of Puebla, near San Nicolas, Tehuacan and several other localities and in the State of Chiapas, near Ixtapa and Tonala.[72]

In the saline of Ixtapa the Indians obtain salt by digging a pit in the Tertiary conglomerate and evaporating the salt water which gathers. A fine white salt is made by boiling the brine in pottery jars.

ROCK SALT.

In the north of Mexico, in the State of Neuvo Leon, at the salt mines of Sabinas, an American company in 1903 put up a plant valued at $70,000 and sank a shaft with the expectation of finding rock salt.[73] It was expected to return a good profit. as the brines had been paying well for years, although the salt

71. Aguilera, Trans. Am. Inst. Min. Eng., 32, 1902, p. 502.
72. Boletin del Inst. Geol. de Mexico, No. 11, 1898, p. 67.
73. Eng. and Min. Jour., March 23, 1903, p. 494.

pits were worked only by burro power and hand-made evaporators.

The primitive way of pumping up brine by burro or mule power in vogue in Mexico is shown in the accompanying photograph (Plate XLII) which shows a mule drawing up an endless chain of buckets full of brine.

According to El Economisto Mexicano, in 1902 there were two rock salt mines in operation, but no description of them was given.

SEA SALT.

Sea salt is produced in lagoons on both the Atlantic and Pacific coasts.[74]

Central America.

Guatemala.[75]

In Guatemala there are strongly saline brine springs in several localities as near the cities of Coban and Quiche. The latter are north of the town and are evaporated for salt in the Saline of La Magdalena.

The Indians and their ancestors have made salt from brines for centuries, but at present nearly all the commercial salt made in Guatemala is sea salt.

SEA SALT.

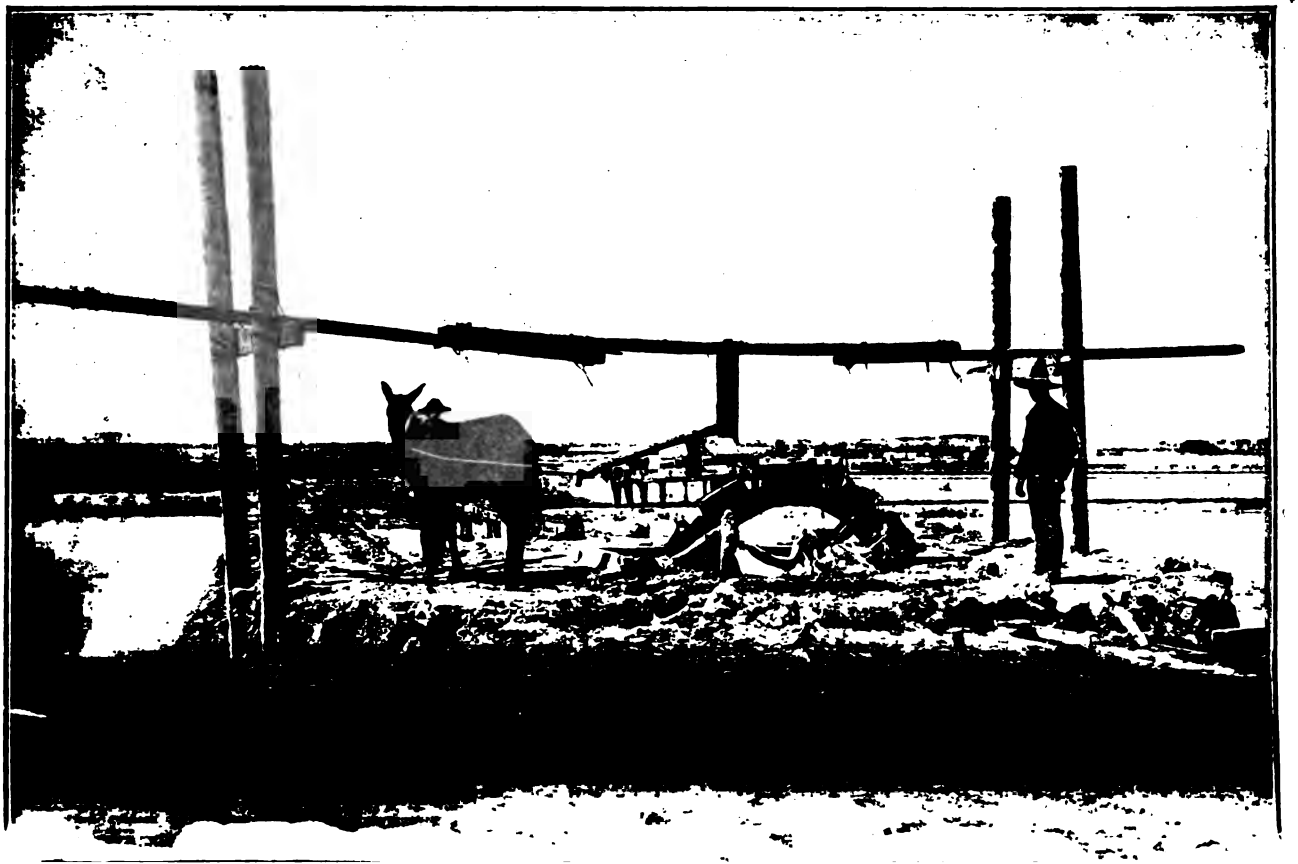
Along the Pacific coast there are a number of salines, of which the most important are those near the harbor of Champeric, where there are four salines of Acapan, Chapan, Ixtan and La Verde.

ROCK SALT.

There are several important rock salt mines near the town of Huehuetenango, which are called the San Mateo salt mines. Small quantities of salt are mined by the Indians in a very primitive way.

The domestic salt is not produced in large enough quantities to supply Guatemala, and salt is imported chiefly from Nicaragua, Peru, the United States and England. In 1904, 2,999 metric tons were imported.

74. Von Buschman, Das Salz, Vol. 2, 1906, pp. 366-367.
75. Von Buschman, Vol. 2, p. 384.



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PRODUCTION AND COST.

In 1902, 2,760 metric tons were produced. The cost of production is about 67 cents per cwt. There is a tax on salt production, but it is not a State monopoly.

In the City of Guatemala in 1903 the wholesale price of doemstic salt was $1.70 per cwt. Imported salt is somewhat cheaper.

Salvador.

No brines or rock salt deposits are known in Salvador and only sea salt is produced.

According to Von Buschman,[76] there are four salines on the coast of Salvador, at Usulutan, San Vincente, Zacatecoluca and Sonsonate.

The production of the salines varies with the weather, but in general is between 2,300 and 3,700 metric tons. Occasionally late rains destroy the harvest, as in 1903, when the price of salt was raised 100%.

Not much salt is imported because of the tariff of $2.40-$2.80 per cwt., which is set aside only in times of great scarcity of salt. Salt can be imported most cheaply from Peru. In past years about 800 tons were imported from the United States, but this has constantly decreased and in 1904 only 26 tons of American salt were imported.

Salvador exports salt to Honduras only.

The price of salt varies at San Salvador from $0.80 to $4.80 per cwt.

Honduras.

As there are no brines, salt lakes or rock salt deposits in Honduras, only sea salt is made.

In the dry season, from November to April, salt is made in primitive ways by the people who live along the coast, and is taken to the villages just before the rains set in.

In 1901, about 2,646 metric tons were made in Honduras.

Small amounts of salt are imported from Salvador, Nicaragua and the United States. The tariff on salt for cooking is $1.40 per cwt.

Salt is exported to Guatemala and Salvador.

[76] Das Salz, vol. 2, p. 390.

Nicaragua.

In Nicaragua, as in Honduras, there are no brines or salt deposits and sea salt is made along the entire coast.

In the sea salines the sea water is evaporated in open vats or earthen jars and a poor quality of salt is obtained.

English table salt is principally imported, and, in 1903, 174 tons were imported from the United States.

Salt is exported from Nicaragua to Guatemala and Salvador. In 1903 the total export was 223 metric tons.

Costa Rica.[77]

As in the other Central American States except Guatemala, there are no brines or rock salt deposits in Costa Rica.

Sea salt is made during the dry seasons, from November to April, in the Gulf of Nicoya, and is then delivered at Puntas Arenas.

Before the protective tariff of 1901 the total production amounted only to about 750 metric tons. Since then it has increased to 2,300 metric tons in 1903 and is likely to continue increasing.

Salt is imported chiefly from Germany and, in 1904, 64 tons were imported from the United States. The tariff is $1.50 per cwt. The domestic salt is used principally for cattle and for salting provisions.

No salt is exported.

The West Indies.

Sea salt is made on a number of the Lesser Antilles and on the Bahamas and on several of the islands north of the Venezuelan coast.

Rock salt has been found only in Santo Domingo.

British West Indies.

On the British West Indian Islands sea salt is made on St. Kitts, Tortola and Anegada, in the Lesser Antilles and on Inagua, Rum Cay, Ragged Islands, Turks and Caicos Islands, in the Bahamas.

Turks and Caicos Islands are the most productive. Two grades of salt are made, a small quantity of finer grade for domestic purposes, and a large amount of coarse salt for packing.

77. Ibid., p. 894.

The salt is prepared by the sun process,[78] as in the Mediterranean salterns. Shallow pools or lagoons are formed and in them the water evaporates. Crystallization begins when the brine becomes concentrated, the crystals being large or small according to the rapidity of evaporation. After sufficient salt has been deposited, boards are laid out on trestles in the water and workmen go into the water with shovels and throw the salt out on the boards, where it is allowed to drain. When dry it is taken into the warehouse and later shipped.

The coarse salt sells at $2.06 per metric ton when the tax of 27 cents on production has been paid to the government.

In 1904 Turks and Caicos Islands together produced 30,951 metric tons. On the average 40,000 metric tons are annually produced, of which 30,000 are exported to the United States. The finer grades are sent to Nova Scotia and the French North Atlantic Islands, St. Pierre and Miquelon.

On the Island of Trinidad mud volcanoes[79] occur in a blue clay formation. The volcanoes eject cold salt water and gray mud with iron pyrites and water-worn pebbles. The volcanoes do not appear to be connected with the sea. Eruptions are most active in the rainy season.

Very pure gypsum[80] is found on the island, but no rock salt. All the salt used is imported.

French West Indies.

On Martinique, Guadaloupe and their dependencies, including a part of St. Martin, sea salt is made in lagoons.

The saline of St. Martin is the most important and produces annually 20,000 to 30,000 barrels. This saline supplies Martinique and Guadaloupe and exports salt to the United States and Canada.

Salt is imported to the French West Indies chiefly from France and in lesser amounts from neighboring islands and from the United States. The tariff is 25 cents per cwt. The selling price is from 15 to 30 cents per cwt.

78 Expert for Robert Crooks Co., New York.

79 Bowen, The Geology of Trinidad, Geol. Journ., vol. 12, 1856, 389.

80 Wall and Hawkins, Economic Geology of Trinidad, Smithsonian Report, 1856.

Dutch West Indies.[81]

Salt is made on the Dutch Islands chiefly at Curacoa, Bonaire, Aruba and the Dutch part of St. Martin. The salt is obtained in coastal lagoons and on Curacoa and Bonaire also in salt pans some distance from the sea. On Curacoa about 25,000 metric tons are produced annually, and some 10,000 exported. In 1903 Bonaire also exported 10,000 and St. Martin 6,000 metric tons.

There is no duty on salt, but there is an export tax in all the Dutch islands except Curacoa and Saba.

The Dutch West Indies export chiefly to North America and to Colombia, in South America, where the sea salines are flooded by the rains and no salt can be made.

Danish West Indies.

Some sea salt is made on the islands of St. Croix, St. John and St. Thomas, but not in large enough amounts to export.

Cuba.

At Salinas Point and several other parts of Cuba there are salines, though as a rule salt is not obtained from them. But near the Chaparra sugar estate there is a salt pan which is separated from the sea by a barrier about half a mile wide which the sea water filters at the spring tides. When it evaporates, a crust of salt is left, which is raked up and harvested. Much of this salt is of a distinct pink hue.

Six sea salines have been in operation in the provinces of Havana and Pinar del Rio since the protective tariff was established in 1903. In 1905 the duty on ordinary salt was placed at 25 cents per cwt. and on pulverized rock salt at 38 cents per cwt.

Salt is imported chiefly from Spain. There is no exportation of salt.

In Santiago, in 1903, the wholesale price of pulverized rock salt was $1.00 per cwt.

Santo Domingo and Hayti.

In the southwestern part of Santo Domingo salt has been obtained for centuries from the Cerro de Sal, or the Salt Mountain of Naybes.[82] It is half way between the harbor of Bara-

[81] Von Buschman, vol. 2, p. 488.
[82] Geol. Journ., vol. 24, 335, vol. 25, 1869, 256.

hona and the salt lake Enriquillo. The mountain is 7 or 8 miles long, 500 yards high and about two miles wide. An immense mass of salt 250 to 300 feet broad, is exposed on the north side of the mountain. The salt is Miocene. The beds are strongly tilted and include layers of pure and almost transparent gypsum. An analysis of the rock salt shows that it is 97.8% sodium chloride.[83] The deposit is not regularly exploited but is dug out by the people here and there in holes. Brine springs are found over a considerable area in the vicinity of the mountain.

In Hayti there are sea salines along the coast, especially at Gonaives, where a poor quality of salt is made.

Not enough salt is made to supply the island, so it is imported, principally from Turks and Caicos islands.

Porto Rico.

There are a number of lagoons around the Island of Porto Rico from which a considerable amount of salt is obtained.[84] The principal salines are those of Coama, Guanica and Sierra de Pinones de Caba Rojo. The owners of all these salines have become wealthy. Sufficient salt for the necessities of the island can be easily produced from these deposits.

In 1903 the wholesale price of salt in San Juan was 40-50 cents per cwt.[85]

South America.

Venezuela.

Only sea salt is produced in Venezuela. It is possible that there are rock salt deposits in the mountains, but no effort is made to discover them, as the production of rock salt is contrary to the Venezuelan laws.

SEA SALT.

A great deal of sea salt has been made in past times along the northern coast from Cumana to Maracaibo and on the neighboring islands, as Margarita, Cayo-du-Sal and St. Roque.

The most interesting of the sea salines is that on the peninsula of Araya, not far from Cumana, which was discovered by

83 Von Buschman, Das Salz, vol. 2, 404.
84 Hill, Ext. 20th Ann. Rept. U. S. G. S., 1898-1899, p. 7.
85 Von Buschman, vol. 2, p. 406.

Alonzo Ninno in 1499. Even then the Guayquerias Ind obtained salt from the lagoon and their ancestors had don since very early times. The Spaniards who settled at Cun ire, appropriated the salt works of Araya and made sea salt t ned from the beginning of the sixteenth century. But as there ans no settled population on the peninsula, the Dutch South Amer can and West Indian colonists made frequent raids on Araya and stole the salt. To prevent this, in 1605, Spain sent armed vessels to expel the Dutch; but even this was not sufficient to stop the contraband trade, and in 1622 a large fortress, the Castillo de Santiago, was built to protect the salt works.

The geological history of Araya is as interesting as its political. Laet, in 1633, wrote that the salt lake was separated from the sea by a barrier above the level of high water. But in 1726 a hurricane of great violence occurred. The ocean broke through the barrier and converted the salt lake into a gulf several miles in length. The old salt works were entirely destroyed. Later, salt pits were made, but the salt could not be so well obtained as from the former lake. Humboldt,[86] at the close of the eighteenth century, visited these "new salt works" and found it hard to believe that the salt of Araya had once been the envy of the English, Dutch and all the other maritime powers.

At the present time ordinarily the lagoon is not connected with the sea. Thus it is evidently returning to its former condition, and it has again become one of the important salines of Venezuela. After a long time without rain the greater part of the lagoon becomes dry. What water remains is three to five feet deep and the salt is obtained from the shallower parts. The peninsula is so intensely hot during the day that the salt is harvested only at night. It is shoveled out of the water, put in baskets and piled up on the banks.[87]

There are also salines at Maracaibo, Barcelona, along the Gulf of Trieste and on the Island of Coche, which is between Margarita and Araya.

[86] Travels in Equatorial Regions from 1799-1804, vol. 2, 1822, 3rd ed., 246.

[87] Von Buschman, Das Salz, vol. 2, 466?467.

The lagoon at Coche is separated from the sea by a barrier 800 yards wide, through which a canal is cut for the entrance of sea water. The salt begins to crystallize in January or February, and in March or April it is harvested. Many laborers are employed and 18,000 metric tons are annually produced

LAWS RELATING TO PRODUCTION AND SALE OF SALT.

The production and sale of salt in Venezuela is a State monopoly, controlled by stringent laws.

Salt can be transported by land or water only with a special permit. All consignments of salt forwarded without such a permit are confiscated and also the ship in which they are sent or the pack animal or conveyances, whatever they may be.

IMPORTATION AND PRODUCTION.

The importation of salt by private individuals is absolutely forbidden by the laws of 1889, 1900 and 1902. Punishment for any attempt to break this law consists in the confiscation of the ship's total cargo and payment of double the tariff and the cost of the proceedings. But, when necessary, the government imports salt from the British West Indies and the Island of Trinidad.

Except for small quantities of English refined salt, imported by way of Trinidad, only sea salt is used in Venezuela.

No salt is exported.

In 1904 Venezuela produced 7,410 metric tons of salt.[88]

British Guiana.

There are no rock salt deposits and no salines in British Guiana. All the salt is imported.

The tariff on refined salt is 75 cents per cwt. and on coarse salt 37 cents. There is an additional 5% revenue tax.

The salt is imported mostly from England and the West Indies. In 1903 the total import was 712 metric tons. Part of the imported salt is reshipped to the Dutch and French West Indies and to Dutch and French Guiana.

The wholesale price in Georgetown (Demarara) in 1903 was $1.30 per cwt. for refined salt and $1.12 per cwt. for coarse salt.

88 Rothwell, Min. Ind., 1906, p. 512.

Dutch Guiana.

No salt is produced in Dutch Guiana, but in the interior the Indians and Buschnegers are said to make small quantities of plant salt from the ashes of a species of palm, as is done in Madagascar, Central Africa and Brazil.

The tariff on coarse salt is 60 cents per cwt. and on refined salt 80 cents per cwt. Attempts to enter salt without payment of duty are punishable by a fine and confiscation of the cargo.

About 300 metric tons are annually imported. The coarse salt is mostly from Barbadoes, Curaçoa and British Guiana, the refined from Holland and England by way of Demerara.

French Guiana.

A small quantity of salt is made in French Guiana, but no rock salt deposits are known.

Nearly all the salt used is imported from France. In 1901, 339 metric tons were imported from that country.

Colombia.[89]

In Colombia sea salt, evaporated salt from brines, and rock salt are produced. The Andes, as in Peru, are rich in salt deposits which are exposed at several places near Bagota, and their presence elsewhere is indicated by the occurrence of brine springs.

SEA SALINES.

There are sea salines on the northern coast on the Caribbean Sea near Magdalena, and on the western coast, on the Pacific, west of Bolivar.

In Panama an impure sea salt is made at Aguadolce.

BRINE SPRINGS.

The saline of Youza is a little northeast of Bogota. The brine from the springs is transferred in large jars, carried by men and women on their heads, to the boiling vats, where it is boiled for five days and nights.

In the province of Antioquia salt is also made from brine springs, which there are a great number. Some contain a large proportion of sodium chloride, while others contain also sodium and magnesium sulphate, which often occur in such

[89] Von Buschman, Das Salz, vol. 2, pp. 451-457.

amounts as to render the brines unfit for use. Iodine is also found in many, and to it is attributed the wide-spread prevalence of goitre among the people who use the salt from these brines. Of the many salines in Antioquia the most important is that of Guaca, west of Medellin, where nine brines of varying degrees of salinity are evaporated. They all contain iodine. These brines flow from Carboniferous beds.

ROCK SALT.

The most important salt mine of Colombia is that at Zipaquira, four hours' drive northeast from Bogota. The salt works look like a fortress, as they are surrounded by strong walls. The traveler Berger, who visited the works, found men employed in breaking up with pickaxes the earthy salt which forms the surface outcrop, while women gathered up the broken-up lumps in baskets, which they emptied in a nearby pool. The brine made in this pool is led in open gutters to the refinery, where, by boiling and evaporating it, a fine white salt is obtained. Rock salt in blocks is also won underground at Zipaquira, where it is mined in large galleries. The salt is often remarkable for its wonderful transparency. The salt works belong to the State and are leased to the mining company

The tariff is constantly changing. In October, 1903, it was set at $2.30 per cwt. on salt entering the Atlantic ports, but in February, 1904, this was increased to $5.70 per cwt. The tariff in Panama is $1.02 per cwt.

The imported salt is from the Island of Curacoa and from the Peruvian maritime salines. In 1904, 76 tons were also imported from the United States.

No salt is exported from Colombia.

The price of salt varies with the grade. In 1903 Curaçoa salt was sold in Colombia at $7.00 per cwt.

There are no estimates of the total production.

Ecuador.

There are a number of brine springs in the Andean region in the west of Ecuador, some of which are a continuation of those in Colombia. According to Buschman one group of brines is in the valley of Patia and another on the plain of Mira in the vicinity of the volcano of Cotapaxi, while still another is

near Ibarra, northwest of Quito. There are also brines at the foot of the volcano of Chimborazo, which flow from beds of trachyte. Salt is obtained from them at the saline of Tomabela.

The cities of Quito and Cuenca use only sea salt, which is made in the mines of Guayaquil.

The importation of salt is contrary to law, except in the case of Peruvian salt coming over land boundaries.

The production and sale of salt is a State monopoly controlled by the Public Treasury. No statistics of production are furnished.

Peru.

Salt is obtained in large quantities in Peru by evaporating sea or lagoon water or brine from saliferous earth in shallow pits called *pozos*. There are also salines where salt is made from brine springs. The Peruvian Andes contain vast deposits of rock salt, which are mined in many localities.

In 1896, the Peruvian Government established a Commission to investigate the salines and salt mines of the country.

SALINAS DE POZO; OR WELL SALINES.

According to the report[90] of the Commission there are salines extending from Tumbes, in the extreme north on the Gulf of Guayaquil, to Ica, about 200 miles south of Lima, thus including almost the entire maritime region.

These salines are all called *salinas de pozo*, or well salines. The pits are usually arranged in rows and sometimes cover a large area. They vary in shape and size and in a single saline there may be any number, from 6 to 400. The water is led in from the sea or from lagoons by canals. Its evaporation is greatly favored by the almost entire absence of rain. Primitive methods are used in harvesting and the salt is of very ordinary quality.

The majority of the *salins de pozo* are sea salines, but inland at Chilca, about 50 miles southeast of Lima, there is a large saline with 300-400 wells where the brine is obtained from a salt lake. And far inland on the high plateau, near the city of Cuzco, there are the salines of San Sebastian and of Maras,

[90] Estudio Tecnico de las salinas del Peru.

on the Urubamba River. In these salines during the summer months water from salt streams near by is led into very shallow pits and evaporated. In the San Sebastian saline there are 900 *pozos*, and at Maras 4,500. The former produces only 113, and the latter 550 metric tons annually.[91] (One metric tons equals 2,205 pounds.)

SALT STEPPE SALINES.

The great saline of Huacho is about 100 miles north of the city of Lima. It is on a steppe, where salt encrustations are formed in shallow water. The salt is allowed to accumulate and is usually extracted only every fourth year. By this method 500 pounds are obtained from every square yard. As in the Argentine, the salt is taken out in blocks, which are called *panes*. The Indians transport the salt by llamas, each animal carrying 100 pounds. The salinity of the plain appears to be derived from saliferous beds, and the composition of the salts is quite different form that of sea water. About 8,000 metric tons are produced annually at Huacho.

A somewhat similar but smaller saline is at Tiquillaco, not far from Lake Titicaca, near the city of Puno, where the brine is also evaporated in pits.

BRINES.

In the province of Huanuco there are a number of brine springs, as those of Santa Barbara. Brines also are found in the province of Junin, near Yanacachi.

ROCK SALT.

East of the town of Cerro de Pasco is a hill of salt which is called the Cerro de la Sal, and from it the Indians obtain salt.

South of the town, on the west shore of the lake, near Junin, is the important rock salt mine of San Blas, where salt deposits occur in Jurassic and Cretaceous beds. The annual production here amounts to 2,070 metric tons.

South of Junin, in the province of Huancavelica, there are two large salt mines, Cachi and El Carmen, and a number that are less important.

In the province of Ayacucho there are also salt mines, two of the largest being near the town of Ayacucho. The salt won in

91 Von Buschman, vol. 2, 434-450.

these mines is of the finest quality and is transported long distances.

There are also salt mines in the province of Apurimac, but the salt is rather impure and is used chiefly for cattle.

Still farther south, in the province of Arequipa, there are a number of rock salt mines, for example that of Huarhua, which Humboldt visited on his travels. There the immense mass of salt is mined in an open quarry and is cut into 60-pound blocks.

Thus in general the rock salt mines of Peru lie in the southwestern part of the country, extending from Junin to Arequipa. But there are also rock salt deposits in northern Peru at Moyabamba and in the valley of the Rio Huallaga. These are however, exploited only by the Indians, who call the outcrops *salinas*. The Indians either carry the salt on their backs in 100-pound blocks for many days' journey through the wilderness, or float it down the river on rafts. This salt contains other minerals besides sodium chloride and the impurities are thought to be the cause of the skin diseases which are very prevalent among the Indians who consume it.

IMPORTATION AND EXPORTATION.

The importation and exportation of salt is controlled by the State. The Government has leased the right to export salt to the Compania Salinera and, according to their statistics, the total export in 1904 was 11,700 metric tons.

The salt is sent chiefly to Colombia and Ecuador and lately in small quantities to Guatemala.

In Lima, in 1903, salt in sacks was worth, at wholesale rates, about $2.00 per 100 pounds.

The production in 1904 as estimated at 18,544 metric tons.[92]

Bolivia.[93]

The high plateau of Bolivia is very rich in salt, especially in the southwestern part, where there are many salt plains and salines like those in the Argentine, lying chiefly in the beds of evaporated salt lakes.

[92] Rothwell, Min. Ind., vol. 14, 1906, 512.
[93] Von Buschman, Das Salz, vol. 2, p. 468.

Of the many salines some of the more important are those of Quetena and Licancaur, near the Chilean boundary, and, further north, the Pampa Salada and the Pampa de Empeza.

The Pampa de Empeza contains very pure salt in a layer more than four yards thick. The salt covers the surface of a shallow lake and the water beneath can be seen only where the Indians have cut out the salt. Near the uppermost part the salt grades into a gray salt clay.

The large salt lake which is formed by the Rio Desaguadera, the outlet of Lake Titicaca, is about 150 miles west of Sucre. Only a single species of fish can live in this lake, *Orestias Agassizi*, and the shores are covered with snowy encrustations of salt.

Salt encrustations are harvested in the valley of Oruro and from the salines of Uyuni and Corocara by Indians, in cubic blocks weighing about 10 pounds each.

As enough domestic salt is produced, only small quantities of refined English salt are imported by way of Para, Brazil.

The tariff in 1901 was set at 25% of the value.

No salt is exported from Bolivia.

Brazil.

In some of the Brazilian States salt is obtained in small quantities from brine springs and saliferous soils. Thus in the State of Ceara,[94] in the clays, there are salt licks which are much frequented by cattle, and some of the streams are salt, especially in the valley of Aracaty-assu.

SALIFEROUS SOILS.

In the west, in the State of Matta Grosso, at the sources of the Paraguay, and in the neighboring State of Goyas, salt is obtained in considerable quantities apparently from saliferous soils.

The most important region of saliferous soils is in the valley of the San Francisco, in the State of Bahia, where a saliferous area extends along the river from its tributary, the Rio de Salitre, not far from the town of Joazeiro, for nearly two degrees of longitude. Here, as Hartt says, one sees, especially

[94] Hartt, Geol. and Geog. of Brazil, 1870, 471.

after rains, white encrustation of salt covering large areas. These are frequently harvested, but more generally the salt is obtained by digging large shallow pits along the river banks. During the rainy season the saline materials are washed into these pits from the surrounding soil and later, when the water has evaporated, the floor of the pits is covered with salt. This is scraped up and thrown into wooden troughs and mixed with water. The earthy material is then allowed to settle and the brine is drawn off and recrystallized in the sun's heat. In 1870, Allen saw, at Jacaré, a section of a large hollow tree serving as the leaching tub and smaller hollow logs for the evaporating vessels. The salt is packed in cow-hide bags, each containing 30-40 pounds. The origin of the salt in the soil is unknown. Hartt was unable to find any beds of rock salt near the San Francisco, and none have since been discovered. It is, however, possible that such beds lie some distance beneath the surface and are the source of the salinity of the soil.

SEA SALT.

Nearly all the salt produced in Brazil is made by the evaporation of sea water. This industry is carried on along the entire coast, but principally in the States of Maranhao, Ceara, Rio Grande do Norte, Alagoas, Sergipe, Bahia, and Rio de Janeiro.

Salt is one of the chief products of Rio Grande do Norte, where the largest salines are at Mossoro and Assu.

In the State of Bahia large quantities of sea salt are also made, especially on the Island of Itaparica, in the harbor of Bahia.

PLANT SALT.

As the transportation of salt far inland is costly and as only enough salt is made from saliferous soils to supply the people in the immediate vicinity of the deposits, there is a great scarcity of salt in the interior. So, as a substitute for salt, Karsten says the Indians use cayenne pepper; and Von Steinen found Indians of the Nahuaqua and other tribes preparing plant salt from the ashes of *Takoara* and *Aguape*, which are plants that grow in stagnant water. The method is the same as that used

in Central Africa; that is, the ashes are mixed with water and the filtered solution is evaporated.

IMPORTATION AND EXPORTATION.[95]

Salt is imported from European countries, Argentine, Uruguay, and small amounts from Belgium and the United States.

As the salt is carried by steamers as ballast, the cost of transportation from Europe is not great.

TAXATION AND PRICE.

Salt entering Brazil is subjected to a very heavy tax. In 1903 the tariff on coarse salt was about $8.00 per metric ton and that on the same quantity of refined salt was $31.40. Potassium salts, however, enter duty free. (One metric ton equals 2,205 pounds.

The price of salt varies in different parts of Brazil, according to the distance from the place of production or from the harbors. Up the Amazon, at Manaos, the price of refined English salt in 1903 was $40-$48, exclusive of a revenue tax of $31.40, per metric ton. Refined salt is a luxury, costing in some places as much as 35 cents per pound.[96]

Paraguay.[97]

There is only one saline in Paraguay, which is near Lambare. Salt has been won there in a primitive way for many years, but recently an artesian well 53 yards deep has been driven, which furnishes water with a salinity of 10%. This, after evaporation, leaves a white crystalline salt, which is chiefly used for cattle. In 1902 this saline produced 400 metric tons.

The greater part of the salt imported is sea salt from Spain.

Uruguay.

No salt deposits have been found in Uruguay and there are no sea salines.

All the salt consumed is, therefore, imported. The tariff on sea salt and rock salt is 6% of the value, and on refined salt 31%.

The sea salt is imported chiefly from Spain and the rock salt

95 Von Buschman, vol. 2, pp. 417-420.
96 Ibid, p. 422.
97 Ibid, pp. 473-474.

and some table salt from England and some table salt from Germany.

Argentina.

On the high plateaus and on the low plains of the Argentine there are a great number of shallow lakes (*salinas*), salt marshes (*lagunas*) and salt steppes.

SALINAS, OR SALT LAKES.

The *salinas* extend from the northern boundary of the Argentine down into Patagonia to about 49° S. Lat. Darwin[98] found that they occur in various formations—in the clays and calcareous beds of the Pampas, in the sandstones of the Rio Negro, in which they are very abundant, and in the Patagonia Tertiary formations.

That the salinity is not in general derived from underlying beds of salt rock is shown by the fact that fresh water has frequently been found by borings in the beds of the salinas and near the margins. The presence of rock salt in the mountains is indicated by brine springs, from which salt is made in small quantities.

On the plains in the dry season many localities become covered with an efflorescence of salt. These salt steps are called *salitrales* (saltpeter fields), although they contain very little saltpeter, but chiefly Glauber salts and 16% of sodium chloride. The *saltrales* serve only as licks for cattle.

In the northwestern part of the country, on the plateau of Atacama,[99] which extends over four provinces of the Argentine Republic and continues northward into Bolivia, there are a great number of salt lakes and marshes and salt steppes, some of which are covered with layers of salt two feet thick. Among this group of *salinas* are those not far from the cities of Jujuy, Saltum and Tucuman.

Salinas de Cordoba.—The largest of all the saline depressions of the Argentine is the *salinas de Cordoba*, which lies between the cities of Cordoba and Santiago del Estero. It extends from 28°-32° S. Lat., covering an area of some 200 by 140 miles.

The appearance of this great salt plain varies with the seasons.

98 Geol. Journ., vol. 2, 1846, Pt. 2, pp. 127-128.
99 Von Buschman, vol. 2, pp. 424-434.

As with all the *salinas,* in the dry period the water disappears, leaving the floor covered with encrustations of salt. This consists chiefly of sodium chloride, but contains also magnesium sulphate and gypsum. In general the gypsum is deposited near the margins and the salt toward the center of the basin.

Mr. French, who traveled across this region, describes it as a wide plain, level and smooth as a floor, and snow-white with superficial salt.[100]

San Blas.—On the lowlands there are a great many *salinas* and *salitrales,* extending from the Parana to the Gulf of San Matias. The most productive are those not far from the coast, near Bahia Blanca and San Blas, in the southern part of the province of Buenos Ayres.

The water from the salt lake near San Blas is pumped through cast-iron pipes 26 miles to the town, where it is evaporated. Borings made in the bed of this lake show the presence of rock salt from which the brines flow that feed the lake. The syndicate which controls this industry produces annually some 25,000 metric tons.[101] (One metric ton equals 2,205 pounds.)

Methods of Extracting Salt.—Where the salt forms a compact mass it is cut in large rectangular blocks called *panes,* from their resemblance to loaves of bread. Where the deposit is loose it is packed in raw-hide bags. The salt is often transported to great distances, for which various pack animals are used, chiefly mules. donkeys, oxen and llamas. Two or three *panes* make a load, depending on the strength of the animal.

Although the salt of some localities is fairly pure, in general the salt of the Argentine is not good for cooking purposes, as it is difficult to dissolve; so it is used largely for salting hides. But in Cordoba salt is refined at Quilino and San José and the product, which is 99.62% sodium chloride, is as good as refined English salt.

PRODUCTION.

The salt production of the Argentine was estimated in 1901 as 25,401 metric tons, but this apparently does not include that produced in the less important salines.

100 Nat. Hist. of Salt, London, pp. 21.22.
101 Von Buschman, vol. 2, p. 431.

IMPORTATION AND EXPORTATION.

Table salt is imported from England and Germany and coarse salt from England and especially from Spain. The annual importation from Spain is about 91,000 metric tons.

Salt is exported from the Argentine chiefly to Paraguay and Uruguay. In 1902 the total amount exported was 135,685

Chile.

There are rich deposits of salt in northern Chile, but none have been found in the southern part of the country. Sea salt is made along the northern coast.

ROCK SALT.

In the extreme north there are three salt mines south of Tacna, near Arica, where a rich bed of rock salt is exploited. The salt is taken out in blocks, sent by rail to the port of Arica and shipped on small sailing vessels chiefly to Vladivia, in south central Chile. In 1902 the output of these three mines was 3,541 metric tons.

South of Tacna, between Tarapaca and Iquique, a bed of rock salt of unknown thickness extends over an area of many square miles. This is exploited in the mines of Punta de Lobos. The salt is taken out in blocks, some of which are ground for cooking purposes and the rest are sold for the use of cattle in southern Chile. In 1903, 10,240 metric tons were produced by this mine.

In the province of Tarapaca there are salt plains, as the Pampa Blanca and the Salar Grande, but they are not used.

Saltpeter Deposits.—The great saltpeter deposits of northern Chile, in the provinces of Tarapaca and Antofagasta, also contain salt. The salt is found in the salt steppes, into which the saltpeter areas merge, and in layers bedded with the saltpeter. Sometimes the proportion of sodium chloride reaches 50%, and at Aguas Blanca there are beds several feet thick of pure crystalline rock salt in the nitrates. But the cost of separating it from the other substances is so great that, as a rule, it is not attempted. At Antofagasta, however, a fairly good salt is produced in this way. Lately some potassium salts have been found in the province of Tarapaca.

102 Board of Trade Journ., No. 328, March, 1903.

The deposits of nitrates and salt are called *caliche*. They lie in the dry basins of ancient salt lakes which have long since evaporated.[103]

IMPORTATION.[104]

The extraction of the *caliche* is carried on under the direction of foreign engineers, most of whom are English. Some 30,000 people are employed in the industry. The raw materials are reduced to nitrates destined for the manufacture of gunpowder and for the preparation of artificial manures, and borax and some salt are also produced.

The tariff on ordinary salt was set, in 1902, at 45 cents per cwt.; on refined salt at $1.80 per cwt. Potassium salts enter free.

Salt is imported in small quantities chiefly from England and Spain and also from Germany, France, the Argentine, and the United States. No salt is exported.

CHAPTER III.

SALT IN THE EASTERN HEMISPHERE.

Europe.

British Isles.

GENERAL REMARKS.

Salt is obtained in the British Isles from natural brines and from rock salt deposits. The brines are apparently the direct product of the leaching of the rock salt beds. In former times salt was made from sea water on the coast of Cornwall and near the mouth of the River Tees, in Durham County.

Natural brine is used for making salt in Chester and Worcester, and brine artificially made from rock salt is used in the Tees field in South Durham and Yorkshire and in Antrim County, Ireland.

Rock salt is mined in Lancaster, Chester and Antrim.

All the rock salt deposits of the British Isles occur in the Keuper marls of the Upper Triassic.

In 1905 the United Kingdom produced 2,116,699 short tons.

103 Reclus, Univ. Geog., vol. 18, 432.
104 Von Buschman, vol. 2, pp. 457-465.

valued at $2,707,622.[1] It ranks second in production to the United States.

THE CHESHIRE SALT TERRITORY.

The Cheshire salt territory lies in the valley of the Weaver and its tributaries, the Dane and the Wheelock.

The output is obtained principally from rock salt, or the brine derived directly from it.

Geological Occurrence.[2-6]—The Keuper marls of Cheshire lie in an elongated basin with an axis running nearly north and south. The rock salt occurs in isolated patches within the marls.

Winsford and Northwich are the principal salt localities. It has also been found and worked near Lawton.

In the Northwich and Winsford districts the salt occurs in two principal beds which are rather impure. The upper is from 120 to 210 feet below the surface and the lower from 240 to 300.

The lower is about 105 feet thick at Northwich and slightly more at Winsford. A fairly pure zone of salt 15 feet thick occurs from 60 to 75 feet below its upper surface, and is overlain by a bed of red and blue marl from 26 to 30 feet thick containing veins of rock salt. Above this comes the upper bed.

At Northwich the upper bed is from 120 to 180 feet below the surface, 48 to 140 feet below tide level and averages 75 feet in thickness. Its upper surface is very irregular in this district, sloping from Marston near Northwich rapidly to the west and southwest and being furrowed by erosion channels of Triassic

1 Min. Res. of the United States for 1906.

2 "On the Manufacture of Salt in Cheshire," by Thos. Ward, Literary and Philosophic Society of Manchester, 3d series, vol. viii, 1884 (read in 1881), pp. 9-25.

3 "The Rock Salt Deposits of Northwich, Cheshire, and the Results of Their Exploitation," by Thos. Ward, Manchester Geological Soc. Trans., vol. xxv, 1896-98, pp. 274-306, with two maps and a section.

4 "Land Subsidences in Cheshire," by Thos. Ward, Liverpool Geol Assn., Trans., vol. iv, 1883-84, pp. 37-46.

5 "Outline of the Principal Geological Features of Cheshire and the Adjoining Districts," by G. W. Ormerod, Quarterly Journal of the Geological Society, vol. iv, 1848, pp. 262-288, with map and sections.

6 "A Sketch of the Natural History of the Cheshire Rock Salt District," by H. Holland, Transactions of the Geological Society, vol. i, 1811, pp. 38-61.

and recent origin. At Winsford this salt bed is somewhat thicker and more than 180 feet from the surface. It is rather impure and contains a large proportion of marl.

Above the salt are 90 to 200 feet of marl, in which gypsum occurs locally, and the marl is overlain by glacial drift.

A section of a boring at Marston is given below:

Formation.	Thickness. Feet.	Total Depth. Feet.
1. Soil and drift	32.0	32.0
2. Keuper marls	92.0	32.0
3. First bed of rock salt	90.50	214.50
4. Indurated marls with salt veins	27.92	242.42
5 Second bed of rock salt	91.75	334.17
6. Hard red and blue marl with salt	30.66	364.83
7. Rock salt	5.17	370
8. Hard red and blue marl with salt	8.17	378.17
9. Rock salt	12.50	390.67
10. Hard red and blue marl with salt	23.50	414.17
11. Triassic (sandstones, etc.) down to	.....	2,610

The following section published in 1848 shows the occurrence of salt in the Lawton district:

Formation.	Thickness. Feet.	Total Depth. Feet.
1. Soil and gypseous marls	126	126
2. Salt	4	130
3. Indurated clay	30	160
4. Salt	12	172
5. Indurated clay	45	217

The upper bed of salt is here about 290 feet above sea level.

Methods of Working.[7, 8, 9]—Salt is Made in Cheshire by the evaporation of brine; it is also mined directly as rock salt.

A large amount of water leaches through faults and fissures in the marl above the first salt bed and forms a strong brine on its upper surface. Before the discovery of rock salt the brine was taken from springs and wells in the marls. Since then it has been worked by cylindric shafts, sometimes 10 feet in diameter, driven down to the surface of the bed. In some of these shafts the brine formerly rose as much as 150

7 See Footnote No. 2, page 132.
8 See Footnote No. 3, page 132.
9 Engineering, Sept. 26, 1884, p. 290.

feet above the salt. Later, however, the enormous amount of brine consumed in the district, 4,000,000 gallons per day in 1881, lowered its level very considerably.

It now stands below the upper level of the rock salt. No brine penetrates to the lower bed of salt, but some of the abandoned mines in this formation have been used as brine reservoirs, a few of them holding over 50,000 gallons.

Evaporation is carried on in open pans set over brick flues with a furnace at the front end and chimney at the other. In this way the products of combustion pass directly under the pans.

The *upper bed* of salt was discovered in 1670, but mining did not begin in earnest until about 1730.

In working the upper mines a shaft was usually sunk for some distance down into the clay, a tunnel was then driven sideways and another shaft called the "sump" sunk into the salt. From the bottom of the "sump" the salt was worked out in annular chambers; pillars about 15 feet square were left on the circumference, one row of pillars being opposite the openings in the following row. Sometimes radiating galleries were worked out from the bottom of the shaft with walls of salt between. The chambers were 35 feet high in some mines. The salt was hauled by windlasses and horsepower.

A mine in the lower bed, of which a description was published in 1884, had chambers 23 feet wide by 26 feet high. (Most of the lower mines have the chambers 18 feet high.) This shaft was sunk directly to the second bed of salt; the salt was worked by compressed air cutting machines; the hauling was done by ponies over tramways and the salt was crushed at the head of the shaft.

Most of the upper mines did not last long. Inrushes of brine and the collapsing of the roof, due to weak pillars, were the chief causes of their abandonment. At present there is but one such mine in existence. Since 1781 most of the mining has been in the lower bed.

Subsidences.—The collapsing of the mines and the large quantities of brine pumped in the district has brought about

extensive subsidences of land through the Chesire territory.

The sinking of the surface forms large depressions which fill with water and are locally known as flashes. One of these flashes near Northwich is 100 acres in area and about 45 feet deep.

In the Northwich and Winsford district about 2,800 acres of land had subsided in 1881 with a direct damage to property of $2,304,000. Buildings in the town of Northwich have suffered most severely from this cause.

These subsidences occur in almost all the English salt districts, including the Tees, where the salt is from 900 to 1,700 feet from the surface.

History and Production.[10, 11, 12]—Salt has been produced in Cheshire since the occupation of the country by the Romans. It was formerly made from brine springs and in the Doomesday Book, which was compiled in 1086 in the reign of William the Conquerer, there is a record of salt works at Nantwich, Middlewich and Northwich.

The opening of the East Indian market to English salt and the development of alkali works later on were great factors in increasing the output of Cheshire salt.

STAFFORD.

Between 28,000 and 57,080 barrels[13] of evapoated salt were produced in Staffordshire yearly from 1882 to 1892. Since 1893 the statistics of its annual output have been included with those of Cheshire.

Shirleywich and Weston on Trent are mentioned by authors as the localities from which this salt is derived.

LANCASTER.[14]

At a point one and a half miles southeast of Fleetwood rock salt was discovered by a boring in 1880, and it has also been found at Barrow. Areas underlain by salt are indicated by

10 See Footnote No. 2, page 132.
11 See Footnote No. 3, page 132.
12 Great Britain Min. Stat., 1882-1905.
13 1 ton equals 2,240 pounds, 1 barrel equals 280 pounds.
14 Manchester Geol. Survey, vol. 16, p. 26.

surface subsidences at Birkdale near Southport, at Southshore near Blackpool and northward near Ulverston.

History and Output.[15, 16]—In the seventeenth century salt is said to have been made by the lixivation of blown sand along pounds.
the part of the coast lying between the mouths of the Mersey and the Ribble.

Both brine salt and rock salt are now produced in this country.

The present industry began in 1890 with 63,016 barrels of salt. In 1905 2,182,872 barrels were produced.

THE TEES.

This salt area is situated on both sides of the estuary of the Tees River in Durham County. (See Plate XLIII.)

The source of production is a bed of rock salt underlying the field at depths of from 900 to almost 1,700 feet.

Occurrence.[17, 18 19]—The salt bed varies from 65 to about 120 feet in thickness, the thinning out being in some cases as much as one foot in sixteen.

The occurrence of the bed of salt is perhaps most clearly shown in the section of a boring put down at Saltholme in 1874. From the sections and the accompanying map it will be seen that the salt lies about 460 feet deeper in the Greatham boring than at Ormesby, four miles south, and still deeper at the Eston hole about two and a half miles east-northeast of Ormesby. A careful study of the twenty or more bore holes put down indicates a dip of from 2° to 3° to the southeast, north of the Tees. This increases to about 5° near the Tees and flattens out to about 3° south of the river.

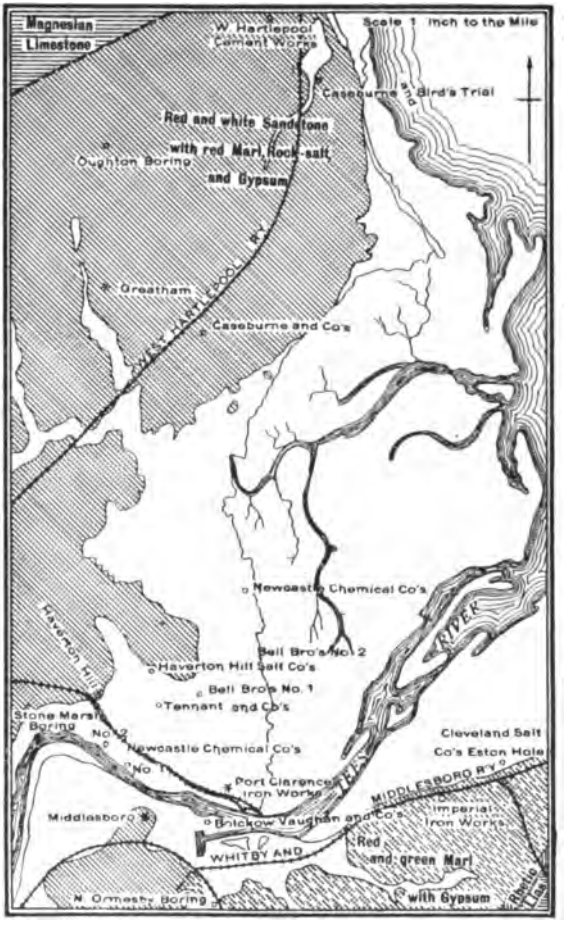
15 Great Britain Mineral Statistics for the years 1882 to 1905.

16 1 ton is intended to be equal to 2,240 pounds or 8 barrels of 280

17 "On the Durham Salt District," by E. Wilson, Geol. Jour., vol. 44, 1888, pp. 761-782, with map and sections. A full discussion of the history of the field and occurrence of salt.

18 "Recent Borings for Salt and Coal in the Tees District," by T. Tate, Geol. Jour., vol. 48, p. 488.

19 "The Middleborough Salt Works and the Recent Boring on the Lackenby Foreshore Estate," by Thos. Bell, Manch. Geol. Soc., vol. 20, 1888-90, pp. 555-561; also Manch. Geol. Soc. vol. 25, 1896-8, pp. 69-83.



SALT DISTRICT OF THE TEES, ENGLAND

E. WILSON, GEOL. JOUR., VOL. 44, 1888

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before in connection with salt works in the United States.

20 "On the Durham Salt District," by E. Willson, Geol. Jour., vol. 44, 1888, pp. 761-782, with map and sections.

21 "Salzbergbau und Salienbunde," F. A. Furer, Braunchweig, 1900, p. 271.

22 "On the Manufacture of Salt," by Lowthian Bell, Proc. Inst. Civil Eng., vol. 9, 1886-7, with diagrams.

23 "Middlesborough Salt Deposits," Eng. vol. 36, 1883, pp. 341-2, with diagrams. Detailed account of the manufacture and uses of salt, with diagrams of well.

The brine is evaporated by the open pan process and moulded into hard blocks, which are ground up and screened for table salt.

History.—In 1862, when boring a well for water to supply the iron works at Middleborough, a bed of rock salt 100 feet thick was discovered 1,206 feet from the surface. An attempt to sink a shaft to this deposit failed on account of the influx of water.

In 1874 a trial boring was put down by Messrs. Bell, who found salt at a depth of 1,127 feet. Later on two more wells were sunk and worked by the artificial brine method which was then introduced into England for the first time, having been used before at Nancy, in France.

Production.[24]—In 1905 1,501,560 barrels were produced. Each square mile of the field is estimated to contain about 100,000,000 tons of salt.

WORCESTER.[25, 26]

Occurrence.—Salt is made in the Worcestershire field entirely by the evaporation of brines. These brines come from a horizon of Keuper marls, which are red, friable and regularly stratified, containing bands of gypsum and of sandstone. The marls lie in a trough of Lower Keuper sandstone which dips to the south and is bounded by faults on the east and west. They are underlain by Permian beds.

The area underneath which brine exists in paying quantities is about six miles long by 300 yards wide. It extends from Stoke, four and a half miles southwest, through Droitwich, to a point west of that town.

At Droitwich the brine occurs in what is apparently a cavity in the marls at a depth of from 200 to 210 feet from the surface. Parkinson, who described this cavity in 1884, estimated it as half a mile long by 200 yards wide.

24 "The Tees Salt Industry," Trans. Fed. Inst. of Min. Eng., vol. 3, 1891-92, p. 632. Also Mineral Statistics of Great Britain, 1882-1905.

25 "The Droitwich Brine Springs and Saliferous Marls," by C. Parkinson, Quarterly Jour. Geol. Society, vol. 40, 1884, pp. 248-266.

26 "The History of Salt," by C. M. Boddy, London, 1881, p. 28.

Two hundred and twenty feet is probably the bottom of the cavity.

According to Boddy[27] a shaft at this place, sunk to a depth of nearly 500 feet, passed through four layers of salt, aggregating 85 feet in thickness. At Stoke the brine occurs at a depth of 800 feet from the surface.

Several bands of excellent rock salt are found in beds of red and gray marl and gypsum, which are at least 800 feet thick. The rock salt occurs within a bed 25 feet thick, of softer marls and sandstones, almost 800 feet from the surface.

Method of Working.—Rock salt was mined for a time at Stoke at a depth of 800 feet, but the mine was abandoned because of an inrush of brine.

In 1855 brine still came to the surface in some of the pits, but now it is pumped from a depth of 210 to 220 feet at Droitwich and 800 to 1,000 feet at Stoke.

History and Production.[28]—The Romans made salt in Worcestershire and partly paid their soldiers with it. This was the origin of the word salary from the Latin *salaria* (*sal*-salt). Salt furnaces are mentioned in this region in the early records as far back as the year 816. In 1725 the strong brine springs below the gypsum bands were discovered, and in 1884 one spring is said to have produced 8,000 barrels of salt per week. In 1905 1,347,888 barrels were produced.

ANTRIM.[29, 30]

In the county of Antrim, Ireland, rock salt is mined, but part of the product is dissolved at the surface and evaporated. The salt is exploited along a belt two miles long, parallel to the shore, north of Carrickfergus, which is ten miles northeast of Belfast. The field consists of three small basins: the Duncrue, Burleigh and Eden. Salt also occurs at Larne, a few miles further north.

27 Ibid, p.33.
28 Great Britain Mineral Statistics, 1882 to 1905.
29 Kelly, Proc. Royal Irish Academy, 1866-69, pp. 262-264.
30 Miscampbell, Trans. Fed. Inst. Min. Eng., vol. 7, pp. 546-552.

The salt, like that of England, is of Keuper age and occurs in several fairly thick beds interstratified with red and blue marls, clay and local bands of gypsum.

A bed as found at a depth of 603 feet two miles northwest of Carrickfergus, and at a depth of 550 feet two miles directly north of the town. The shaft of the first successful mine was put down 360 yards southwest of the latter locality and the following strata were passed through:

	Thickness. Feet.	Total depth. Feet.
1. Drift	50	50
2. Marl with gypsum	416	466
3. Rock salt	11	477
4. Marl and rock salt	5	482
5. Rock salt	74	556
6. Marl and rock salt	5	561
7. Rock salt	37	598

The following is an analysis of a sample of the rock salt:

Moisture	2.48
Magnesium chloride	.03
Potassium chlorid	.15
Sodium chloride	96.17
Oxide of aluminum	.35
Silica	.82
	100.00

Method of Working.—Mining is done by shafts and tunnels, as in Cheshire. The salt is worked by rock-cutting machines. Some of the mines have been abandoned on account of the crushing of pillars. At the surface of the mine are melting cisterns, in which part of the rock salt is reduced to brine. The brine is conveyed by iron pipes to Carrickfergus and there evaporated.

History and Production.—The first discovery of salt in Antrim county was made in 1839 at Larne, ten miles north of Carrickfergus, while boring for coal. Later, in 1845, salt was found near Carrickfergus.

In the Mineral Statistics for Great Britain and Ireland several localities are quoted as having salt works where evaporated salt is made from a brine formed by dissolving rock salt in sea water.

The records of the Irish output show a marked fluctuation in the production of salt from year to year; but the average from 1893 to 1902 was 351,448 barrels. In 1905, 390,920 barrels were produced.

ISLE OF MAN.[51]

The northern part of the plateau of the Isle of Man is a plateau covered with glacial drift and underlain by northward dipping strata. Triassic marls with several beds of rock salt were found in two bore holes, one at Point of Ayre, in the extreme north of the island, the other 400 yards to the southeast.

Germany.

Before the discovery of rock salt in Germany the brine springs were of great value. Salt as made from many of these even in very ancient times; and Tacitus tells of furious wars between the Germanic tribes for the possession of these springs, which were held as sacred. Brines flow in Germany from horizons ranging from the Devonian to the Cretaceous.

Among the most productive[52] were those of Stassfurt, east of the Harz Mountains, which were noted even in the seventeenth and early in the eighteenth centuries. These ceased to be profitable after the discovery of rock salt and were abandoned in 1860,[53] but in many other localities brines are still used. The German salines are shown on Plate XLV.

THE DISCOVERY OF ROCK SALT AND POTASSIUM SALTS.

In 1837 the Prussian government began a series of experimental borings for richer brines or rock salt, as the 22 salines then in operation were unable to supply the market. And the first discovery of rock salt was made during that year in Thuringia, at Artern.[54]

Two years later a boring was begun at Stassfurt, which was continued interruptedly, and in 1843 the upper beds of the salt deposit were reached at a depth of 816 feet. But the salt, instead of being pure sodium chloride, as had been hoped, was found to

51 Boyd Dawkins, Geol. Journal, vol. 58, pp. 648-661, with map and sections.

52 For further description of the brines see Meyer, Zeitschr, fur-prakt. Geol., May, 1894, p. 212, and Furer, Salsbergbau, p. 24.

53 Precht, Salz Industrie von Stassfurt, 1885, p. 3.

54 Berg und Huttenmannische Zeitung, vol. 61, p. 1902.

contain a high percentage of chlorides of potassium and magnesium. The great value of the deposit was not realized, and it was abandoned as worthless.

Later, in the Duchy of Anhalt, near Stassfurt, a boring was made which entered a bed of very pure rock salt beneath the potassium salts.[35] Encouraged by this the government reopened the Stassfurt boring in 1851 and on sinking it deeper reached purer salt. The first shaft, "Von der Heydt," was completed that year and the mining of the rock salt was begun. In 1856 a very pure bed of salt was entered at 1,066 feet. Meanwhile the really valuable potassium salts were removed to obtain the rock salt beneath and were called the *Abraum* or stripping salts, a name they have retained to the present time. Finally the piles of these rejected salts so surrounded the mine as to make it difficult to extract the salt. The mine was also on the verge of failure because the production of rock salt exceeded the demand. Then the superintendent, Krug von Nidda, thought of the possibility of utilizing the waste salts and, in 1861, the first factory for the manufacture of potassium chloride was started at Stassfurt. The remarkable growth of the industry is shown by the fact that twelve years later there were 32 factories in operation.

Efforts were made to find potassium salts east and northwest of Stassfurt and a number of successful shafts were sunk as at Loderburg and Westeregeln. West of Stassfurt potassium salts were first found in Brunswick at Thiede, in 1872.

In 1894, borings for these salts were carried on in Brunswick by the government for two years. A row of bore holes was made along the southern slopes of the Asse and Heeseberg ridges. Rock salt was found at depths of 872-1,544 feet. The first salt bed was 656-820 feet thick; potassium salts followed this with a maximum thickness of 239 feet, and beneath these usually a second rock salt bed was found, estimated to be about 328 feet thick. The northern slopes of the hills were found to include salt beds at a depth of 1,968 feet and continued through 656 feet and were then not penetrated. The potassium salts

35 Larbaletrier, Le Sel, 1900, p. 117.

36-37 Consult Kloss, Zutschrift fur prakt. Geol., p. 111, March, 1895. Also Berg und Huttin., Zeitung, vol. 56.

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[58] J. Kloss, Zeitschr. fur prakt. Geologie, 1895, p. 117 et seq.
[59] Lang, Berg und Huttenmannische Zeitung, vol. 58, 1899.

DEEP BORINGS.

An idea of the thickness of the Permian salt deposits of northern Germany can be formed from the results of deep borings. To the east at Inowrazlaw[40] near the boundary of Russia, the salt which lay at a depth of 420 feet was found to continue through 600 feet, when the boring was discontinued without reaching the base. And to the north, in Mecklenburg-Schwerin, at the village of Probst-Jesae, a well was sunk 3,960 feet and throughout the lower 3,000 feet rock salt was passed through, but the bed was not penetrated.[41]

Up to January, 1900, 76 borings for salt had been made between 4,231 and 2,273 feet. Of these, 22 were 3,280-4,231 feet; 40, 2,624-3,280; and 14, 2,273-2,594 feet.[42] So many have been made between 1,640 and 2,296 feet that it would be difficult to record them.

The most interesting deep boring is that at Sperenberg, south of Berlin, where the following section was made:[43]

	Feet.
Detrital material	2.06
Bluish-gray gypsum	279.48
Nearly white anhydrite with gypsum	5.14
Pure anhydrite	1.96
Anhydrite with rock salt	2.62
Pure, transparent rock salt	3,879.06
Total depth	4,170.32

Thus 3,879 feet of salt were penetrated without reaching the base of the deposit.

An estimate was made at Sperenberg of the rate of increase of the earth's internal heat.[44] The temperature at the bottom of the bore hole was 48.1° Centigrade. The annual minimum temperature of Sperenberg—as found in springs—is 9.75° Centigrade. The total increase is 38.35°. At a depth of about 72 feet the constant temperature is reached. A column

40 Schubert, Nutzbaren Lagerstatten von Inourazlaw, Zeitschrift, Berg-Hutt. und Salinenkunwessen, vol. 28.
41 Eng. and Mining Journal, April 12, 1884.
42 Zeitschr. fur prakt. Geologie, 1900, p. 29.
43 Furer, Salzbergbau, 1900, p. 205.
44 Eng. and Mining Journal, May 5, 1904.

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45 From Precht, Die Salz Industrie von Stassfurt und Umgegend, 1885, plate.

46 Fuchs and De Launay, Traite des Gites Mineraux, pp. 434-437.

The salt at Stassfurt is generally in compact, crystalline masses, with cleavage in three directions. On a large scale it does not show stratification. There is also a fibrous variety, found at Douglashall, northwest of Stassfurt along fault planes, the fibres being perpendicular to the fault, and a granular variety which forms thin white or yellow bands. The yellow color is due to iron chloride, which is present in the proportion of 3.75 per cent.

The only fossils found in the salt are microscopic plants thought to be mosses.

The salt contains liquid and gaseous inclusions which can often be seen as bubbles in the mass. Gas also fills the fissures in the salt. At the Douglashall mine in 1875 the gas caught fire and burned with a flame 5 feet high, the fire lasting from April to June. This gas was analyzed and found to consist of the hydrocarbons (methane, etc.), 85 parts; carbon dioxide, 3 parts; and air, 12 parts.

Although the salt in the lower beds is very pure it is of little value because of the difficulty of separating out the anhydrite. These bands of anhydrite are composed of small crystals of anhydrous calcium sulphate cemented by rock salt. The anhydrite is often bituminous and of a greyish color. In 1865 Reichardt found sulphur grains adhering to the anhydrite. The upper surface of the anhydrite is smooth, the lower, rough and uneven.

Toward the latter stages of the precipitation of this bed of rock salt the saturation point of some of the potassium-magnesium salts was reached and the anhydrite bands were replaced by polyhalite, forming the polyhalite bed, which is about 100 feet thick.

As the rock salt grades into the polyhalite horizon, it requires a bitter flavor and becomes less crystalline, transparent, and more deliquescent. This is due to the presence of 5 per cent of magnesium chloride. The polyhalite is bluish-gray in color and has a conchoidal fracture.

The salt is valueless and is thrown aside or used for gobbing. Efforts made to separate sulphate of potassium from the poly-

halite have been unsuccessful. Thus the polyhalite zone has no economic use.

Above this is the kieserite region, which also contains some carnalite. The average composition of this zone is 65% rock salt, 17% kieserite, 13% carnallite, and 5% anhydrite. The amount of carnallite gradually increases in the upper layers of the kieserite region which then merges into the carnallite zone.

The carnallite zone is the most valuable of the entire series. Its thickness is 60 to 130 feet. It forms the upper portion of the "lower salt bed." Its average composition is 55% carnallite, 26% rock salt, 17% kieserite, and 2% anhydrite.[47]

The carnallite, a double chloride of potassium and magesium, is white and transparent when pure, but varies from yellow to brick red when it contains impurities. The luster is less vitreous than that of the rock salt, the solubility and the deliquescence much greater. The carnallite forms stratified beds with a maximum thickness of 6 feet, alternating with bands of rock and kieserite which diminish upwards. The carnallite beds form bands of different colors varying from bluish gray, caused by the presence of bituminous matter, to rose or bright red, caused by iron oxide. In the hanging wall the bituminous material become quite abundant.

In addition to iron oxide, quartz, rutite, boracite, kainite, sylvite, stassfurtite, and tachyhydrite are found in the carnallite zone. The quartz crystals are colorless or rose, and in the middle of the zone many broken crystals are found which seem to have been rolled and sometimes show evidence of a second crystalization.

The carnallite contains many microscopic fossil fragments which Schmidt has attempted to identify with the flora and fauna of the Zechstein.[48]

Salt Clay.—The carnallite zone is followed by a layer 25 feet thick of salt clay, formed partly of muddy materials and

[47] H. B. Nitze, "Stassfurt Salt Deposits," Mines and Minerals, Scranton, June, 1899, p. 521.

[48] Traite des Gites Mineraux, p. 443.

partly of precipitated magnesia. The clay is of great importance, as it protected the easily soluble salts beneath from being washed away by the flooding of the bay which is indicated by the presence of the anhydrite overlying the clay. This protection afforded by the clay was so complete that the chlorides have preserved their crystal form, but deliquesce instantly on exposure to the air.

An anhydrite bed 130 to 300 feet thick forms, usually the base of the clayey shales of the Buntsandstein which overlies the salt beds.

The Upper Rock Salt Bed.—In certain localities, as in the Ludwig II mine, there is an upper bed of rock salt, 130 to 400 feet thick. It differs from the lower bed in its greater purity, containing 97% to 98% sodium chloride. The polyhalite rings are hardly visible and lie about a foot distant from one another. The occurrence of this bed is very local, as is shown in the section of the two mines. In the Ludwig II mine the upper salt bed is well developed, but it is wholly lacking, a mile away, in the Van der Heydt mine.

The Buntsandstein, composed of variously colored clayey shales overlies the salt deposits.

Primary and Secondary Minerals.—In addition to the minerals which have been mentioned above as occurring in the Stassfurt salt deposit, there are a number of others, some of which are very rare. These in many instances are of secondary origin. The following list is from Precht:

STASSFURT MINERALS.[49]

Primary Group.

Rock salt	$NaCl$
Anhydrite	$CaSO_4$
Polyhalite	$2CaSO_4+MgSO_4+K_2SO_4+2H_2O$
Kieserite	$MgSO_4+H_2O$
Carnallite	$KCL+MgCl_2+6H_2O$
Boracite	$Mg_7B_{10}O_{30}Cl_2$
Douglasite	$2KCl+FeCl_2+2H_2O$

[49] See also Larbaleterie, le Sel, p. 124.

Secondary Group.

Kainite.....$K_2SO_4+MgSO_4+MgCl_2+6H_2O$
Sylvite.....KCl
Schoenite.....$K_2SO_4+MgSO_4+6H_2O$
Langbeinite.....$K_2SO_4+2MgSO_4$
Reichardite.....$MgSO_4+7H_2O$
Jarosite.....$K_2SO_4+Fe_2SO_3O_12(Fe_2(OH)_6)$
Krugite.....$K_2SO_4+MgSO_4+4CaSO_4+2H_2O$
Glauberite.....$Na_2SO_4+CaSO_4$
Astrachanite.....$Na_2SO_4+MgSO_4+4H_2O$
Glaserite.....K_2SO_4
Bischoffite.....$MgCl_2+6H_8O$
Tachyhydrite.....$CaCl_2+2MgCl_2+12H_8O$
Pinnoite.....$MgB_2O_4+3H_2O$
Ascharite.....$3Mg_2B_2O_5+2H_2O$
Heintzite.....$KMgH_2B_{11}O_{20}+6H_2O$
Kaliborite.....$Mg_2KH_2B_{11}O_{20}+6H_2O$
Magnesite.....$MgCO_3$
Iron pyrite.....FeS_2
Sulphur.....S

Geological Structure.—As shown by the cross section through Stassfurt, the salt deposits are no longer in their originally horizontal position, and they have undergone great changes, resulting from dynamic and chemical action.

After the deposition of the salt beds the floor of the ancient salt sea was gradually raised in an anticlinal fold. This extended in a southeast and northwest direction and divided the original surface into two basins and constituted the Stassfurt-Egeln ridge or saddle. This elevation began very gradually during the deposition of the Buntsandstein, and continued probably even to the close of the Tertiary.[50]

Along the crest of the ridge the salt beds were entirely dissolved away and the space they occupied has been filled in with detrital material. This process of removal by solution extended so far that now the uppermost edge of the rock salt is 230 feet, and that of the carnallite 656 feet beneath the surface.[51] The carnallite, along its upper borders, has been altered by contact with water into sylvite, kainite and allied substances.

[50] [51] Precht, Salz Industrie von Stassfurt, p. 8.

Conditions of Deposition.—During the deposition of the salt beds of northern Germany the low-lying areas were covered with a land-locked sea. On the east side this sea bordered the older highlands of Magdeburg and Alvensleben and on the south the foothills of the Thuringian forest. The western shore line is thought to have passed from the Island of Heligoland in the North Sea, through Stade and Luneburg in the Elbe valley to Porta on the Weser and then up along the valley of that river.

Rock salt was deposited over the entire sea floor, extending over Altmark, Mecklenburg, part of Holstein and the present valley of the Lower Elbe, but it was only in the narrow Harz gulf that the extreme degree of concentration necessary for the precipitation of potassium salts was reached. In this gulf after the deposition of rock salt the richest deposit in the world of potassium salts was formed.

To account for the depth of the salt we must suppose a constant inflow of fresh saline materials. This seems to have entered through a narrow canal, so shallow that there could be no return flow along the bottom of the concentrated salt solution. Such conditions now exist in many instances, as in Karabugas Bay, which receives saline materials from the Caspian Sea and deposits them as beds of rock salt. This is exactly comparable with the supposed conditions of deposition in northern Germany.

After the formation of the main mass of the lower rock salt bed the Harz gulf was completely closed by a barrier and became a dead sea. By continued evaporation the density was reached at which the potassium salts were deposited, first as polyhalite, then as kieserite and finally as carnallite.

After the formation of the carnallite the floor of the dead sea became almost dry. Dust swept by the winds from the barren shores covered the carnallite and formed the salt clay. Immediately after the water broek through the barrier and flooded the gulf. Then followed the deposition of the anhydrite.

The floor of the gulf again became nearly dry, but water heavily charged with salt gathered in the depressions and deposited the locally developed upper salt bed.[52]

[52] Precht, Salz Industrie von Stassfurt, p. 7.

The salt formation was then flooded by the ocean and the sandstone beds deposited.

Mines and Mining Methods.[53]—In 1900 there were eleven mines in operation in the Stassfurt area. The depths of the shafts vary from 300 to 700 feet. The following mining methods[54] are in use, depending on the angle of dip, the thickness of the bed and the firmness of the potassium salts.

When the beds are thick, nearly horizontal but loose, cross cuts to the carnallite are driven from the shaft every 160 vertical feet. The salt body is worked in overhand stopes 13 feet high by 39 feet wide, with pillars 16 feet wide, extending throughout the entire vertical thickness of the bed.

Where the carnallite bed is steeper and firmer, the stopes are driven from hanging to foot-wall 32 to 39 feet wide and 19 to 22 feet high. Pillars 97 feet wide are left every 130 feet along the strike, extending from floor to roof.

Where the bed is nearly vertical, with a tight hang-wall, working drifts 35 feet high by 6 feet wide are driven parallel to the main levels and connected with the same at intervals by crosscuts. The stopes are driven 45 feet high and 22 feet wide. The pillars are 32 to 39 feet thick, according to the potassium contents.

All empty stopes are immediately filled wtih gobbing of rock salt. Only about 40 per cent of the carnallite is won, the remaining 60 per cent being left as pillars.

The rock salt, which is characterized by much greater solidity than the potassium salts, is mined by the pillar and stall system, the rooms being made 65 feet wide by 30 feet high.

Both hand and machine drilling is used. A slow acting powder is used for blasting. In the carnallite bed one cubic yard is broken by one and one-fourth pounds powder in drift work, and only five and a half ounces in stope work. One miner can break ten gross tons in drifting and forty gross tons in stoping per eight-hour shift.

53 Furer, Salzbergbau, 1900.

54 H. B. Nitze, "Stassfurt Salt Deposits," Mines and Minerals, June, 1899, p. 522.

In 1900 the Syndicate of Potassium Salt Works employed 818 supervisors and 15,600 workmen.

The total value of the raw and elaborated potassium salts in the same year was $14,750,000.

Uses of Potassium Salts and Their Products.—The kainite and sylvite are chiefly ground in the raw state and sold as fertilizer.

The carnallite, kieserite and other potassium-magnesium salts are converted into chloride, sulphate and carbonate of potash, sulphate of magnesia and glauber salts. Small quantities of solid chloride of magnesia, bromine, bromides and hydrochloric acid are also produced.

The potassium chloride is used principally in the manufacture of saltpetre, potash, potassium chromate, potassium-aluminum chloride, and is also, like the kainite and sylvite, valuable for agriculture.

Kieserite and glauber salts are obtained as by-products in the manufacture of potassium chloride. Kieserite, when still further purified, is used in the manufacture of cotton goods.

Potassium-magnesium sulphate is made from the kainite and is largely used in agriculture.[55]

SALT DEPOSITS OF HANOVER.

In Hanover the character of the salt formation differs in some respects from its typical development at Stassfurt. For example, instead of the *upper* and *lower* rock salt bed there is one great mass of rock salt, which contains in the upper horizons inclusions of anhydrite, salt clay and potassium salts.[56] Instead of the regular succession of beds as at Stassfurt, the salts occur very irregularly, so that two borings only 1,968 feet apart in a horizontal line show the potassium salts in entirely different horizons. The salts differ greatly in purity, color and structure. They contain calcium and magnesium sulphates, potassium chloride, iron and clay. The rock salt varies from transparent to opaque and may be fine or coarse grained. The presence of sulphuretted hydrogen is sometimes very noticeable.

[55] For further discussion of methods of manufacture, see H. B. Nitze; loc. cit., p. 522.

[56] "Uber Tiefe Kalisalzbohrungen," Zeitschr. fur prakt. Geologie,

The richest potassium salt deposits in Hanover are in small lenses as at the Benther Hill mine near the city of Hanover.

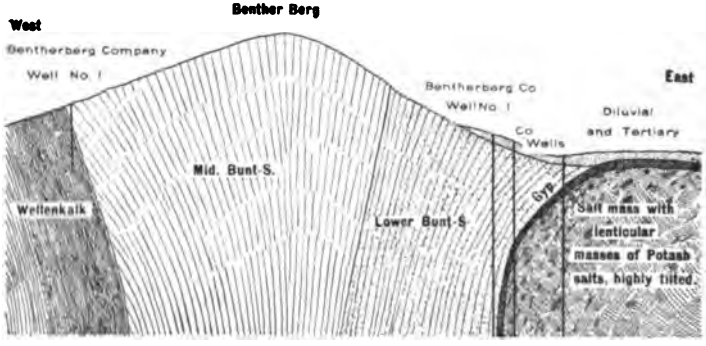

Fig. 22—Section of the Benther Hill Salt Mine, Germany. (Kloos, Zeitschr, fur prakt, Geol., 1897.)

The deepest borings in Hanover have not yet reached the base of the salt mass, although some have gone down 4,650 feet. It may therefore be possible that the Hanover mines are in the very thick upper rock salt bed of the Stassfurt area, which even in Stassfurt contains here and there lenses of sylvitic potassium salts.

Deep Borings and Sections.—The deepest boring in the Province of Hanover is at Salzdetfurth,[57] where the following beds were penetrated by the drill: Buntsandstein, 734 feet; rock salt with carnallite, 1,476 feet; salt clay, 1,871 feet; rock salt, 2,040 feet; carnallite with rock salt, 2,112 feet; hartsalz, 2,125 feet, rock salt, 4,626 feet. Later this was carried to 4,650 feet, but the base of the deposit was not reached.[58]

In Hanover the rocks have been very much faulted. This

[57] Kloos, Zeiftschr, fur prakt Geologie, 1897, p. 414 et seq. 1900, p. 29.

[58] Eng. and Mining Journal, April 7, 1907.

complex structure is shown in the following section at Dehnsen, where the overthrust plane which follows the base of the rock

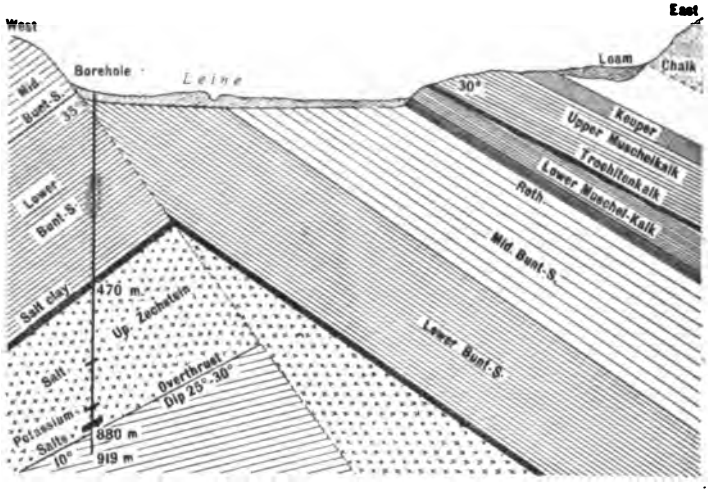

Fig. 23.—Section of Salt Deposit at Dehnsen, Germany, with Overthrust Fault.

salt is at an angle of 25°-30°.

A similar fault occurs at Meimerhausen, where the overthrust plane is at an angle of 60°. Its effect has been to raise the Upper Zechstein (Permian) in which the salt occurs above the Buntsandstein (Lower Triassic).

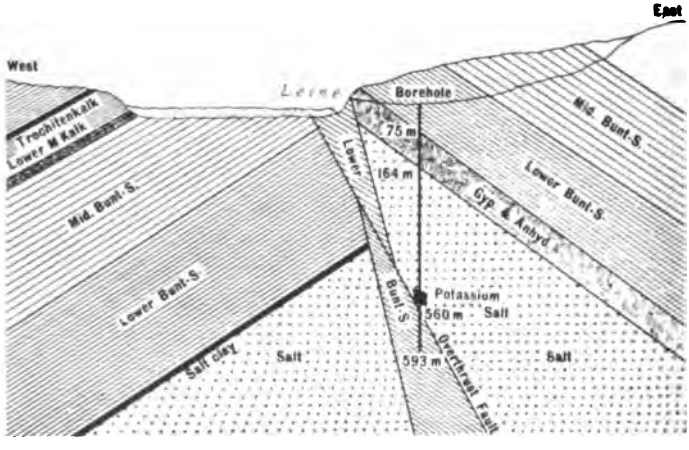

Fig. 24.—An Overthrust Fault in the Salt Deposit at Meimerhausen, Germany.

59 J. H. Kloos, Zeitschr. fur prakt. Geologie, 1897.

These conditions have been explained as due to the formation of a north and south ridge, fractured along its main axis so as to allow the eastern and western limbs to collapse inward in such a way that in the southern part the western and the northern part the eastern limbs lie deeper than the opposite members.[60]

SALT DEPOSITS IN WURTEMBURG.

Age and Occurrence.—In Würtemburg the salt is mined chiefly in three regions: At Heilbronn, Friedrichshall and Jagsfelt; at Hall and Wilhelmsglück; and at Schweningen. (See Plate XLV.).

The salt is all in the Muschelkalk (Middle Triassic). It reaches its maximum thickness at Heilbronn, but is insignificant when compared with the enormously thick Permian salt beds of northern Germany.

Sections.—The following section[61] at Heilbronn shows the succession and thickness of the beds:

	Feet.
5. Principal dolomite region	36
4. Principal anhydrite region	101
3. Intermediate formation	26+
2. Rock salt	131+
1. Basal anhydrite (about)	19

In the rock salt are three horizons: The upper, 39+ feet; the middle, containing the so-called Heilbronn anhydrite, 29 feet; and the lower, 62 feet thick.

At Wilhelmsglück on the Kocher, a little south of Hall, the depth of the strata are very similar to those at Heilbronn.

Section at Wilhelsmglück:

	Feet.
5. Principal dolomite region	26
4. Principal anhydrite region	95
3. Intermediate formation	26
2. Rock salt	16-39
1. Ground dolomite	29

60 Furer, F. A., Salzbergbau, 1900, p. 152,

61 K. Endriss, Die Salzstein formation in mitteren Muschelkalk Wurttemberg: Stuttgart, 1898, Abs. in Zeitschr, fur prakt, Geologie, 1899, pp. 22-24.

LESSER SALT AREAS.

In addition to the Stassfurt, Hanover and Heilbronn areas salt is obtained in smaller quantities in Baden, Franconia, Thuringia, Lorraine and occasionally from thin beds in the Lower Rhine Valley. (See Plate XLV.)

Baden.—At Dürrheim in Baden, two borings[62] have been made; one on Geisinger Street, the other at the Holzplatz.

The first begin in the Gypskeuper and reaches the Middle Muschelkalk at 381 feet and the Wellenkalk (also Middle Triassic but beneath the Muschelkalk) at 678 feet.

Franconia.—In Franconia borings for salt have been successfully made at Bergrheinfeld and Klein Langheim.

Thuringia.—In Thuringia in the Glückauff salt mine at Sonderhausen a complete electric plant was installed.[63] Power is supplied from a central station to all the mines and works. A current of 500 volts is led down the shaft to the landing by a steel-armored cable, 61mm. in diameter, with 3 copper wires of 77 sq. mm. in cross section.

Lorraine.—The salt deposits of Germain Lorraine at Dieuze are described on page — in connection with the French deposits at Nancy, of which they are a continuation.

Lower Rhine Valley.—In the Lower Rhine Valley between Dusseldorf and Aix-la-Chapelle thin beds of rock salt are occasionally met with in coal borings in the red beds beneath the Buntsandstein. These salt beds are of interest only as they rest directly on the shales overlying the carbonaceous deposits.

PRODUCTION.

In 1905 Germany produced 1,959,401 short tons of salt, valued at $4,329,496.—[64]

EXPORTS AND IMPORTS.

The potassium salts of Germany are exported to all the countries of the civilized world.

[62] Sauer, A., Geol. Specialkarte von Baden, 1901.
[63] Eng. and Mining Journal, 1899, July 22, p. 94.
[64] Min. Res. of the United States for 1906, advance chapter on salt by T. A. Coons.

There is a protective tariff of 1 cent per 10 pounds on foreign salt entering through the land boundaries of Germany, but none on that entering along the sea coast.[65]

Norway.

Norway has a saline at Walloe on the bay of Christiania east of Tonsberg, which has been in operation since 1738. In this saline salt is evaporated from sea water in which imported rock salt has been dissolved.[66]

There are also a few weak brine springs of no economic use. In 1898 Norway produced 1,250 tons.[67]

Sweden.

At Torpa in west Gothland several borings have shown that a bed of post-glacial clay 100 feet thick and of considerable extent has been infiltrated with iodine and chloride salts.[68]

There are a few weak brine springs.

Denmark.

Like Norway and Sweden, Denmark has only a few weak brine springs.

The Netherlands.

In the Netherlands there are a few weak brine springs of no economic value, but there are salt refineries in which imported salt is evaporated.

Belgium.

Recent borings near Beeringen, Belgium, have resulted in the discovery of a deposit of rock salt at a depth of 3,280 feet. Further explorations will be undertaken, as the discovery is considered important.[69]

The first concession for carrying on test borings has been lately granted to M. Dumont of Louvain.[70]

65 Furer, Salzbergbau, pp. 248-249.
66 Furer, Salzbergbau, p. 288.
67 Statistique de l'Industrie Min., Paris.
68 Nordstrom, "Om Torpa Saltkalia," Geol. Foren, Stockholm Forh., vol. 2, pp. 236-241, and plate.
69 U. S. Consul G. W. Roosevelt's report, quoted in Eng. and Min. Journal Dec. 20, 1902, p. 809.
70 Communicated, October, 1906, by M. van der Broeck, a director of the Geological Survey of Belgium.

France.

IMPORTANCE AND LOCATION.

France is one of the important sea salt producing countries of Europe. The total area covered by the salt works is about 19,000 hectares, in 12 Departments, 7 on the Mediterranean and 5 on the Atlantic coast. In this industry some 8,000 laborers are employed for several months every year. One of the most important concerns is that of Pechiney & Co., at Marseilles.[71]

Deposits of rock salt are found in Lorraine, on the slopes of the Jura Mountains and on the slopes of the Pyrenees. The salt from the Jura region is very pure and white, that from the Pyrenees is grayish or reddish with a decided fragrance of violets. It usually has a finer flavor than the eastern salt.

Lorraine.—The salt of Lorraine is near Nancy, in the Departments of Meuthe and Moselle. The salt lies in two horrizons, the Upper and Middle Triassic.

The Upper Triassic beds are the most valuable. They are exploited near Nancy, French Lorraine, Dieuze and German Lorraine. (See Plate XLV.)

The Middle Triassic salt beds are in the Muschelkalk and were discovered in 1832 by a boring at Luneville. They are of the same horizon as the salt of Württemberg.

Salt Mines of Nancy.—The salt mines in the vicinity of Nancy lie to the eastward of that city in the valley of the Meurthe and Sanon, from Nancy to Rosiéres-sur-Salines and Einville-au-Jard.[72] The salt occurs in somewhat flattened lenses, lying nearly horizontally and separated by saline clays. Similar lenses of gypsum are also found.

The clays surrounding the salt and gypsum are raised into domes which has been explained as due to the expansion resulting from the conversion of limetone into gypsum in the presence of sulphur.[73]

The saliferous beds have a slight dip of 1-2cm. per meter, thus contrasting with the much folded beds of the Jura region.

71 Furer, Salzbergbau, 1900, p. 269.

72 I. E. Fuchs and L. De Launay, Traite des Gites Min., 1893, pp. 483-484.

73 De Lapparent, Traite de Geologie, p. 1035.

The salt lenses are very variable in number and thickness, and lie at a depth of 131 to 787 feet beneath the surface.

The salt includes two sets of beds which are separated by clays. Only the upper set is exploited and is best developed at the Saint Nicholas mine which is the most important salt work of France and is managed by Marchéville, Daguin & Co. The upper horizon there comprises 11 beds of salt, which have a combined thickness of 213 feet, running through a depth of about 285 feet.

In the eleventh salt bed the salt is quarried out and is sent to the refinery in block form. The salt is 68 feet thick.[74] The total length of the galleries, including the old and new fields, is now 79,983 feet, and the finished chambers have an area of 3,574,902 feet.[75]

Although the rock salt is mined in the eleventh bed at Saint Nicholas and at mines at Rosières and Saint Laurent, in general the salt in Lorraine is obtained by converting it into artificial brine, the fresh water being pumped down the drill holes.

The drills of Saint Nicholas mine were operated by steam until 1899, when this was replaced by an electric plant put in at the Madeleine. The brine is carried by underground pipes from Saint Nicholas 5 kilometers to the refinery. The salt is graded according to the time of crystalization and consequent fineness in 6, 9, 12, 24, 48, 72 and 96 hour salt. About 700 cbm. of brine are obtained daily. Soda is made by the ammonia process.

Salt Deposits of Dieuze.—The saline beds diminish rapidly to the eastward of Nancy, but they apparently continue to the northward and join the salt deposits of Dieuze, Vic, Moyenvic, Chambrey, and Chateau-salins, in German Lorraine, where the salt is in the same horizon as at Nancy.[76] The gypsum keuper at Dieuze varies from 197 to 279 feet in thickness and consists of brightly colored clays in which the salt and gypsum are included. As at Nancy, the salt lenses are limited in area, but often 196 to 213 feet thick. The salt is mixed with a bituminous

74 Furer, Salzbergbau, p. 268, 1900.

75 Berg und Huttenmanische Zeitung, vol. 60, 1901, pp. 485-486.

76 H. Bucking, "Geologie von Elsass-Lothringen"; abstract in Zeitschr. fur prakt. Geologie, 1899, p. 90.

clay, sulphate of lime and soda, and a little sulphate of magnesia, but it contains no magnesium chloride nor any trace of iodine or bromide.[77]

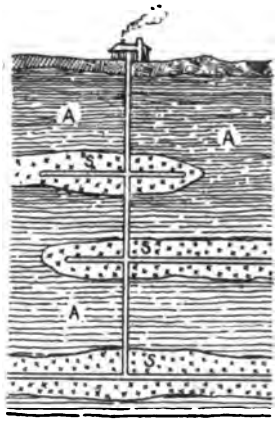

Fig. 25.—Salt Mines in Clay. Lorraine. (Larbeletrier, Le Sel, 1900.)

To the northeast of Dieuze, at Sarralben, rock salt occurs, as at Lunéville in the red and variegated clays of the Muschelkalk.

There are also salines at Salzbronn, Haras and other towns near Saaralben from which kitchen and glauber salts are obtained.

Antiquity of Lorraine Mines.—The salt mines of Lorraine date back to the Roman occupation. Near Marsal, a little west of Dieuze there are ruins which show that mining was carried on there by the Romans on quite a large scale.

SLOPES OF THE JURA MOUNTAINS.

Salt is found in this region in the Departments of Doubs, Jura and Haute-Saône.

Department of Doubs.—In this Department, in the vicinity of Besancon (see may, page 141) the salt industry has been developing for the last twenty years. Important salines are at Miserey and Chatillon, and in 1889 successful borings for salt were made at Pouilley-les-Vignes. Rock salt has since been found in other localities.

77 De Lapparent, Traite de Geologie, p. 1035.

The salt horizon at Besançon appears to be a little lower in the Keuper than that of Lorraine and is equivalent to that of the Tyrol.

Section at Besançon.[78]

		Feet.
	Gryphæa limestone	***
Lower Lias	Schistose marls	75
Keuper	Variegated marls	59
	Dolomite	26
	Red marls with gypsum	75
	Compact gray dolomite	32
	Alternating grayish marls and oil horizons	48
	Variegated marls with gypsum	131
	Rock salt	***

The salt is reached at various depths, as at about 656 feet at Pouilley-les-Vignes and at 580 feet at Miserey.

In this region the beds have all been folded in a northeast and southwest direction, being parallel to and a continuation of the folds of the Jura Mountains.

Borings have been made in both the anticlines and synclines. In general those in the synclines, as the one at Misery, have given the best results. This is because the underground water tends to remove the salt from the anticlines and wash it down into the synclines.

Mining is carried on wholly by dissolving the rock salt, the fresh water being forced down through the drill holes.

The annual production of the mines of Miserey and Châtillon is about 9,000 tons each.

Department of Jura.—At Montmorot, a hamlet near Lons le Saunier, Salins, Arc, and Grozon there are large salines which furnish about 30,000 tons of salt.[79] There are also salt mines at Salins, Grozon, and Montmorot.[80] The rock salt is converted into artificial brine as in Lorraine; but after the pumping has been continued for some time the brine loses some of its salinity. The process is then discontinued until the liquid has dissolved enough salt to form a completely saturated solution.

78 Fuchs and De Launay, Traite des Gites Mineraux, p. 482
79 Fuchs and De Launay, Traite des Gites Min., p. 483.
80 Larbaletrier, Le Sel, p. 97.

THE PYRENEES.[81]

In the southwestern part of France in the Department of Basses Pyrenees salt is most abundant near Salies-de-Bearn. Saline beds are found also in the Landes and extend northward as far as Dax. At Dax these Triassic beds, which contain salt and bypsum, rises in ridges and bossess from beneath the later rocks. The salt is in lenticular masses. It was accidentally found by boring for mineral water in the ditch of an old Roman fortification.

The whole region abounds in mineral springs which are highly charged with salt and rise from the saliferous Triassic rocks. Secondary deposits of salt have been formed by these springs of various geological horizons. In general the salt deposits on the Spanish slope of the Pyrenees have been deposited by evaporation in lagoons, while those of the French slope lie in extinct craters, old valleys and various hollows and have been formed as sec ondary deposits by the brine springe.

The thermal springs are even more important than the salt deposits of Dax. The springs extened ten miles along the Adour valley and form the western limit of the salt. Over 500 tons of mineral water flow daily from these springs, the water having a temperature of 147° Fahrenheit.

Salt is obtained at Briscon, Orthis and Salies-du-Salat by dissolving it through drill holes. At Villefranque rock salt is quarried, but dissolved at the surface to refine it.

No borings have yet fathomed the salt of the Pyrenees, although a depth of 1,082 feet has been reached at Salies-du-Salat.

PRODUCTION AND COST.[82, 83]

The production of France, including Algeria, in 1905 was 1,275,361 short tons, valued at $3,594,818.

The salt industry in France is a government monopoly and concessions for operating mines and salines are granted to private companies. In 1904 there were 29 such concessions.

[81] Stuart-Menteath, Geol. Bag., new series, decade 5, vol. 1, 1904, pp. 265-272.

[82] Communicated by M. Ramond of the Museum d'Histoire Naturelle, Paris.

[83] Min. Res. of the United States for 1906, "Salt," by A. T. Coons.

The average price per metric ton is $1.30 for unrefined salt and $6.34 for refined salt, these rates not including the revenue tax.

Price of Labor.—There are 281 workmen employed in the mines and 1,126 in the evaporating plants. Their wages are 82 cents a day.

TARIFF AND REVENUE TAX.

The present tariff on refined salt imported into France is 22 cents per hundredweight; on refined salt 30 cents.

The internal revenue tax[84] is now $1.00 per 100 pounds. Philippe VI, in 1340, first placed the manufacture and sale of salt under the control of the royal treasury. In the old regime salt became extremely dear and even the poorest peasants were compelled to purchase a certain quantity *per capita*, for themselves and each of their children. For five centuries this tax, called *La Gabelle,* was one of the most oppressive and hated taxes of the monarchy. When under Henri II it was fraudulently increased the people finally refused to buy salt at the royal warehouses and there were several massacres. Louis XVI, shortly before his execution, in a vain attempt to win popular favor, suppressed the tax, but the First Empire restored it and increased it to $3.60 per 100 pounds. In 1848 this was reduced to the present rate.

EXPORTATION.

France exports salt largely to Belgium, the Island of St. Pierre for the fisheries, to Brazil and Madagascar.

Spain.

OCCURRENCE, AGE, ETC.

Sea water is the main source of the salt manufactured in Spain, as in Portugal and Italy.

Cadiz and San Fernando, just south of Cadiz, harvest anually a large amount of sea salt, and it is also evaporated at other localities along the southeastern and southwestern coast.

Brine springs occur all along the southern slopes of the Pyrenees from the Bay of Biscay to the Mediterranean. In the Province of Teruel saline Triassic beds give rise to a number

84 Larbaletrier, Le Sel, pp. 141-144.

of salt springs, some of which were used for many years by the State.[85]

On the southeastern slopes of the Pyrenees there are deposits of rock salt which reach their greatest development at Cardona in Catalonia, about 86 kilometers northwest of Barcelonia on the Cardonero River. The country in this region is a rather high plateau deeply dissected by the river. On both banks, but especially near Cardona, there are such masses of rock salt that salt seems to take the place of ordinary rock and one might say that the city was built on the salt.[86]

THE CARDONA SALT DEPOSITS.

The salt deposit lies in the center of an anticline, from which the upper beds of Oligocene sandstone have been removed by erosion.[87] The deposit is deepest at the head of a small valley about half a mile in length, which runs from the river to the mines in a general east and west direction. On entering the valley the attention is at once arrested by bold cliffs of a grayish-white color, which consists of one vast mass of salt.[88] At the upper end of the valley the salt forms a rugged precipice. This mass of salt, which is 4 kilometers in circumference and 400 to 500 feet high, has often been called the salt mountain.

Its precipitous form is partly due to the way in which it has been exploited, as for centuries the salt has been worked down perpendicularly, as in an open quarry.[89] (See Plate XLVII.)

The surfaces of the salt precipice which have been long exposed to the weather are cut in shallow, tortuous channels, with edeges so sharp as to cut the hands like broken glass. The whole surface has a striking resemblance to a mass of ice which has been partly thawed and frozen again. Ford has compared it to the face of a glacier. The colors, he writes, vary extremely and are brilliant in proportion as the weather is clear, showing in the sunshine all the tints of the rainbow.

85 Cortazar, Daniel de Fisico-geologico de la Province de Teurel, Madrid, 1885, p. 277.

86 Fuchs and De Launay, Traite des Gites Mineraux, pp. 498-9.

87 L. M. Vidal, Comte-Rendu de l'Excursion. Bull. Soc. Geol. France, 3me Ser., vol. 26, 1898, p. 727.

88 Trail, Trans. Geol. Soc. London, 1816, pp. 401-412.

89 Vidal, Bull. Geol. Soc. London, 1816, pp. 404-412.

Pl. 18.

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QUARRY IN THE "SALT MOUNTAINS" OF CARDONA, SPAIN
Vidal, Bull. Soc. Géol. France, Vol. 26, 1898)

FOLDS IN THE CARDONA SALT
(Vidal, Bull. Soc. Géol. France, Vol. 26, 1896)

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The salt is nearly pure in the lower beds, where very fine cubic crystals are found containing gaseous and liquid inclusions. The upper beds are banded with red, so that that part of the mountain of red salt. The salt without losing its compactness. becomes veined. These veins, which are only one to several centimeters thick, are greatly crumpled and sharply folded, evidently as the result of very great lateral pressure. This folding of the salt beds is shown on Plate XLVIII.[90]

Gypsum sometimes overlies the salt, or is intercalated as bands in the salt; and sometimes it forms a mixture with the salt and clay in which very rarely iron pyrites occurs.

Age of the Cardona Salt.—Marcel de Serres and Joly found in the red rock salt of Cardona remains of Infusoria to which they were inclined to ascribe its red or green color.[91] Aside from these no fossils have been reported from the Cardona salt, and owing to this scarcity of organic remains, the age of the deposit has not been satisfactorily determined.

Vidal and Dollfus[92] think it is Oligocene and this is in general the opinion of the Spanish geologists. An argument strongly in favor of this is the fact that saline beds are found associated with Oligocene strata in anticlinal folds in nearby localities. as to the west of Cardona the saline clays of Vilanova de la Aguda, in the Province of Lérida lie in an anticline of Oligocene marls. There the salt does not appear at the surface, but its presence is indicated by a small brine spring and there are many sink holes which resemble those of Cardona. To the south of Cardona at Suria there is a small salt bed which is also in an Oligocene anticline.

SALT DEPOSITS OF THE EBRO VALLEY.

There is a salt deposit of some importance between Capparosa and the Ebro River. The salt is five feet thick and lies between the gysum and clay.[93]

90 Vidal, Bull. Geol. Soc. France, vol. 26, 1898, Pl. 14.

91 G. Birchof, Chem. and Phys. Geol., vol. 1, 1854, p. 354.

92 Bull. Soc. Geol. France, 3me Ser., vol. 26, 1898, pp. 728, 731. M. Carey, however, thinks the salt is Triassic (729), and MM. Bergeron and Deperet that the salt may be Triassic and the gypsum Oligocene (731).

93 Fuchs and De Launay, Traite des Gites Minéraux, p. 499.

A much more important salt bed is at Remolinos, 40 kilometers north of Saragossa, on the left bank of the river, where the salt mines are very famous. The village is built against a high cliff of gypsum and salt in layers alternating with pulverized clayey marls. The salt mass is very thick, but it is mined only during a few months of the year, so as to get enough to supply the province, although large quantities could be quarried out if desired

The salt deposits of the valley of the Ebro were probably formed during the Miocene and perhaps also at a later period, in a gulf which was open to the sea at its mouth, while its upper valley was occupied by salt lakes which on evaporating formed the salt deposits.[94]

THE SALT MINE OF MINGLANILLA.

The mine of Minglanilla,[95] in the Province of Cuenca, ranks next to Cardona in the production of rock salt. The mine seems to have been first opened by the early inhabitants of Spain. It formerly was Crown property, but is now carried on by a private concern.

The old entrance into the mine was down a winding wooden stairway with over 200 steps. The salt is quarried out in galleries 32 feet high and wide, the roofs being supported by pillars. The salt water near the shaft is collected in a well 32 feet deep, from which the brine is raised to the surface and evaporated.

The salt lies in the Triassic. The deposit is 131 feet thick and yields pure rock salt throughout. Eight hundred thousand kg. are yearly mined.

The rock salt is usually ground and put in sacks holding 60 to 80 pounds, and carried on donkeys to the warehouses or the nearest railroad station. Large lumps are sold for the use of cattle.

The contract wages of the workmen who furnish their own light and tools are 20 *centesimos* for every 200 pounds mined.

A saline is run in connection with this mine. The same methods are used as on the sea coast; that is, the brine is run into shallow reservoirs and allowed to evaporate in the sun.

94 Bull. Geol. Soc. France, 2me Ser., vol. 11, 1854.
95 Furer, Salzbergbau, pp. 277-280.

This saline produces 1,600,000 pounds of salt annually which equals the amount of rock salt produced.

THE MINES OF VILLARUBIA.

At Villarubia, near Ocana, in the Province of Toledo, there are rock salt mines in which Glauberite is sometimes found.

A salt deposit at Posa, near Burgos, resembles the Maros-Ujvar salt mass in Hungary.

PRODUCTION.[96, 97]

In 1905 Spain produced 543,931 short tons of salt, valued at $736,074.

EXPORTATION.

Salt is exported from Spain chiefly to Africa and to South and Central America. Competition with English salt has greatly reduced the Spanish trade.

Portugal.

Portugal[98] is one of the chief sea salt producing countries of Europe.

Even in the time of Pliny the town of Setubal, then called Cetobriga, was renowned for the excellent salt manufactured there, and to this day it is one of the important centers of the salt industry. The sea salines (*Marinhas*) furnished not only enough salt for home use but a large quantity is exported. The number of the salines was, however, much greater in former times than now. In 1790 there were 2,863, many of which have since been abandoned. The salt is of three grades: 93%, 89% and 80% sodium chloride.

The best grade comes from St. Ubes, near Palmella, Setubal and Alcacer do Sal. The next best is from the salines of the Tagues, near Lisbon. Other sea salines are at Figueria, Aveiro, Porto and Vianna, and in the south at Castromarin, Tavira, Faro and other localities.

Brine springs occur on the right bank of the Tagus at Rio Major.

96 Min. Res. of the United States for 1906.
97 Rothwell, Min. Industry, vol. 13, p. 381.
98 Furer, Salzbergbau, pp. 280-281.

The Portuguese sea salt contains less moisture than the French and, as it can be sold at a cheaper rate, it damages the French trade very considerably.

The sea salt of Portugal is particularly valuable for salting fish and meat and it is very largely exported for this purpose.

Switzerland.

In northern Switzerland, in the Canton of Aargau, rock salt beds 19 to 164 feet thick are found in the lower clays of the Muschelkalk (Middle Triassic). The salt is mixed with gypsum and anhydrite. It is converted into artificial brine and evaporated.

In the Canton of Bern small salt beds are found at Farneren and Leissigen.[99]

Bex is the most important salt locality of Switzerland. The deposit at Bex is Jurassic (Lias). In 1554 the first brine spring was discovered there and up to 1832 brine was evaporated for the manufacture of salt; but after the discovery in that year of rock salt the latter has been converted into artificial brine. By this method about 3,000 tons of salt are produced annually.[100]

The production and sale of salt is in the hands of the State.[101]

In 1902 Switzerland produced 50,990 metric tons of salt.[102] Nearly enough is produced for home consumption, but some evaporated salt and sea salt is imported from France, refined sea salt from Italy and table and rock salt from Heilbronn, in Germany.

Italy.

MAINLAND.

Italy is the cradle of the saltern industry. Pliny relates that Ancus Martius, the fourth of the early kings of Rome who reigned from 640 to 616 B. C., was the first who had sea water led into closed basins to evaporate so that salt could be made. Later many such salterns were established so that even in very early times the manufacture of sea salt was an important industry. An interesting relic of this is the *Via Salaria*—"the salt

99 Furer, Salzbergbau, 1900, p. 22.
100 Larbaletrier, Le Sel, 1900, p. 75.
101 Furer, Salzbergbau, p. 267.
102 Rothwell, Min. Industry, vol. 13, 1905, p. 81.

road''—one of the oldest of the Roman roads which still passes through Rome and was built for the salt trade between Ostia at the mouth of the Tiber and the inland Sabine country.

SEA SALT.

Salt production in Italy, except on the Island of Sicily, is under government control. The salterns or salt farms are either leased to private companies or administered directly by the State through the Minister of Finance.[103, 104]

SALINES.

At Volterra the rock salt brines are evaporated in a saline. The brine is obtained from an artesian well 300 yards deep, and is pumped into open boilers, under which fires are constantly kept burning. About two tons are made every six hours, and some 10,000 tons annually. The salt is sold principally for table use.

At Salso-Maggiore brine is obtained from wells which are sunk to about 40 yards depth.

The more costly evaporated salt manufactured in the salines cannot compete with the cheap sea salt.

SALT AND PETROLEUM SPRINGS.

At San Valentino on the Rio Rocca and San Romano on the Rio delle Viole are springs which contain naptha and salt.[105]

ROCK SALT.

In Italy rock salt is found in Tuscany at Volterra, in the Campania near Naples, in Calabria at Lungro, and in Sicily at Castrogiovanni and other localities.

Volterra.[106]—At Volterra the salt lies beneath Miocene beds composed of gypsiferous clays. The salt was first discovered by Giovanni Targioni in 1716, but the important bed was not found until 1832, when an artesian well was sunk. The drill passed through five beds of rock salt, of which two were found to have considerable thickness, the first 13 feet thick, at a depth of 141 feet and the second, 39 feet thick, at a depth of 282

103 Furer, Salzbergbau, p. 283.

104 Jour. Society of Arts, London, June 3, 1881, p. 609.

105 Ferretti, "Sopra i vulcani di fango," Boll. del R. Comitato Geologico, vol. 9, 1878, p. 179.

106 Bechi, E., Atti della Reale Academia dei Lincei, Ser. 2, vol. 3, Pt. 2, 1876, pp. 45-47.

feet. Since that time a number of other borings have been made in the vicinity of Volterra and the salt is exploited by means of shafts and galleries. The salt of Volterra is very compact and varies in color from white to reddish.

Lungro.—At Lungro in Calabria is a salt mine that has been exploited for centuries and has often been abandoned and reopened.

The salt occurs in irregular beds, alternating with salt clays, which are used for gobbing.

There are two varieties of salt: *Ceroino,* compact, blue or grey, the color disappearing after grinding, and *Formico,* white, and crystalline. The latter sometimes occurs in large, cubic crystals so transparent and handsome that they are made into ornaments.[107]

The modern methods of mining have only lately been introduced and the old rooms were filled up with salt clays. Galleries are now constructed along direct levels. The salt is blasted. In the mine the pure salt that needs no refining is separated from the impure salt (*Salose*) and the salt clay (*Barde*).

The age of the Lungro salt is generally thought to be Miocene and Eocene and Viola thinks it is also in part Triassic.[108]

SICILY.

Sea Salt.—Sea salt has been made near Trapani since 1507. The average production is 200,000 tons. The evaporating pans are about 90 feet square and 15 inches deep. The sea water is brought in by means of windmills. The salt is harvested three to five times a year and the season closes with the fall rains.[109]

Much of the salt is used on the island, but it is also shipped to Scandinavia, Finnland and North America, where it is used for salting fish. The production of sea salt pays well in Sicily in spite of the tax of 33% on the profits and an export tax of 5 cents per ton.[110]

107 Furer, Salzbergbau.
108 Atti della Reale Acad. dei Lincei, ser. 5, vol. 8, pt. 1, 1899, p. 568.
109 Eng. and Min. Journ., Mar. 31, 1904.
110 Berg und Huttenmannische Zeitung, vol. 60, 1901, p. 415.

Rock Salt.—In the interior rock salt is found near the center of the island. The saliferous zone begins south of Nicosia and extends as far as Cattolica, the greatest width is about 20 kilometers and the length about 120 kilometers. The salt occurs as masses which reach the surface or are lightly covered with alluvial. Among the most important are those of Leonforte, Castrogiovanni, Trabona and Racalmuto. At Castrogiovanni the salt which is very pure, forms an escarpment 52 feet high and contains rose-colored concretions of potassium chloride.[111]

The present output of the Sicilian mines is some 15,000 metric tons, but this could easily be much increased.[112]

SARDINIA.

In Sardinia about 150,000 tons of sea salt are made annually. The Sardinian salt is a source of great revenue to the State, to which it is delivered at Genoa, Spezia and other cities, at the price of $1.30 per metric ton and is later sold by the State at $18 per metric ton.[113]

PRODUCTION.

In 1905 Italy produced 482,475 short tons of salt.[114]

Importation and Exportation.[115]—No salt is imported into Italy. Salt is exported to Africa, America, Russia, Sweden and Norway It is used chiefly for salting fish.

Austria-Hungary.

OCCURRENCE.

Salt is produced in Austria-Hungary in the following regions:[116]

The Alps, where most of the salt is produced from salines and a smaller amount of rock salt is mined; the Provinces of Galicia and Bukowina, where there are four important rock salt mines, including a potassium salt works and ten salines; Marmoros, in Hungary, where there are thre salt mines and one saline; Transylvania, where there are nineteen salt mines; the Provinces of Dalmatia and Istria, where sea salt is manu-

111 Ledoux, Ann. des Mines, 7th ser., vol. 7, 1875, pp. 1-84.
112 Furer, Salzbergbau, p. 281.
113 Eng. and Min. Jour., Sept. 13, 1890, p. 320.
114 Min. Res. for the United States for 1906.
115 Furer, Salzbergbau.
116 Furer, Salzbergbau. pp. 249-252.

factured in five sea salines on the Adriatic; the Provinces of Bosnia and Herzegovina, where there are two salines.

THE ALPINE SALT DEPOSITS.

Age.—The salt is Triassic and lies in masses between the upper and lower Alpine limestone. The largest mass is at Berchtesgarden. It extends 4,985 feet from north to south and somewhat more from east to west. Its greatest known thickness is 934 feet. The next in size are those at Aussee, Hallstatt, Ischl, Hallein and Hall.

The salt deposits seem to have been originally deposited as horizontal strata, which by later folding and faulting during the rise of the Alps, between the Miocene and Pliocene period, were broken up into a breccia. Slight orogenic movements continue even today.

The masses of salt are always impure, containing in general a large proportion of clay, and they are often dark colored or reddish. Veins of anhydrite, polyhalite and glauberite are quite common. At Ischl the salt mass is 50-55% sodium chloride, at Hallstatt 70-75%, at Aussee 80-90%.

History.—Salt mining in the Austrian Tyrol dates back to very ancient times. One salt mine has been found that is thought, from the character of the ruins, to be more than 2,000 years old. At Hall mining has been carried on since the fourteenth century.[117]

Hall.—The mines of Hall are about eight miles from the town. They are reached by a path up a narrow ravine and lie in the heart of the wild and beautiful Tyrolese Mountains. The descent into the mine is made from a flight of 300 steps into the midst of the mountain. There 48 chambers have been excavated, each one to two acres in area. One of the galleries is three leagues in length and more than six days would be required to traverse all the galleries.

The method of enlarging a cavern is this: The miners, with heavy pickaxes, detach fragments of the salt from the roof and walls, and when the cavern is partly filled, fresh water is let in to dissolve the salt, and the saturated solution is then con-

[117] Eng. and Mining Journ., Sept. 9, 1882, p. 137.

veyed by conduits from the mine to the manufactory at Hall. So at a given time some of the caverns are dry and miners are at work in them, while others are made temporarily into salt lakes.

Hallstatt.—The mine at Hallstatt is reached by a very precipitous ascent up the face of a limestone cliff, the level of the lowest gallery being 1,200 feet above the lake. When the mine was visited by Sedgwick and Murchison in 1830 there were eight principal galleries from which the salt was extracted, the highest being 2,343 feet above the lake. The salt was estimated by them to be 1,100 feet in vertical thickness.[118] The highest galleries traverse the salt and reach the limestone of the Blossen Mountain, but the range of the deposit in the depths of the mountain is unknown as all the lower galleries terminate in the salt.

The first fire damp explosion recorded occurred in the Hallstatt mine on September 9th, 1664, 20 years before what is generally supposed to be the first historical evidence of the presence of fire damp.[119]

Ischl.—The salt mass at Ischl, like the others of this region, is a breccia of saliferous clay and gypsum, separated from the surrounding gray limestone by an envelope of blue, gypseous shale. Fossils in the limestone are abundant but poorly preserved and include cephalopods, crinoids and corals. Fossil wood has been found in the rock salt at Ischl.

The mine at Ischl is called the Salzberg. The chief entrance is about three quarters of an hour's walk up the mountain from the village. On entering one walks through a long, low, wet and narrow passage to the slide or *rutsch* which leads down into the salt chamber.[120]

The mountain contains a great many of these chambers, which at different periods are filled with fresh water.

The water is later drained off through a deep perpendicular shaft near the middle of the chamber and is then conducted to the evaporating plant.

118 Trans. Geol. Soc., 2d ser., vol. 3. 1835, pp. 301-420.
119 Eng. and Min. Journ., May 5, 1904.
120 Natural History of Salt. London, pp. 100-104.

Mining Methods.—The general method of exploitation in the salt mines of the Alpine region is by constructing a series of galleries at different levels about 131 feet apart. Each connects with the outside by a horizontal tunnel, which opens on the slope of the mountain. In this way many of the mountains in the course of centuries have become actually honeycombed by subterranean passages and caverns.

The salt is all too impure to quarry and is therefore converted into artificial brine. By this process the clay remains in the mine. Two methods are used: the intermittent method and the continuous. The former is used in the mines and consists in filling the galleries and chambers with fresh water. For example, the chamber Prinzessin Hildegarde, which has a surface of 7,000 sqm. furnishes at every filling 36,000 cbm. of brine. This chamber requires seven or eight days for filling and 29 days for dissolving the salt. The continuous method consists in forcing the fresh water down drill holes, the rate at which it is pumped back being so regulated that the brine is always at the point of maximum saturation. The brine is then allowed to clarify in reservoirs and is later evaporated. This method is used in many salines of the Alpine region.

In general, when solutions made from the rock salt are evaporated, first a double sulphate of sodium and calcium, called *schlot* is deposited, then the chloride of sodium, nearly pure, crystalizes out and only sulphate of soda, bromides and iodides remain in solution.

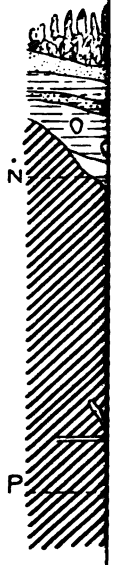
GALICIA SALT DEPOSITS.

The most important salt mines of Galicia are those of Wieliczka and Bochnia, in the northwestern part of the Province, and of Kalusz, in the southeastern part. (See Plate XLIX.)

WIELICZKA.

History.—The first historic mention of Wieliczka, which is about five miles from Cracow, and was formerly called "Magnum Sal," is in the salt concessions granted in 1044 to the Benedictine Monastery at Tyniec by Kasimir I.

Experimental shafts were sunk in 1608-1611, of which the first, Gottes Gnade, was unsuccessful, but the second, Willie Gottes, reached salt masses at the fifteenth fathom level. In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1647 there were eight shafts in operation, three of which have caved many years ago.

Age.—The salt of Wieliczka is a continuation of the Transylvanian Miocene salt deposits. The succession of strata in the Wieliczka mine is as follows:[121] (See Plate L.)

General Section.

1. Yellow sand.
2. Red loam.
3. Fine sand with clay.
4. Marl and clay with boulders.
5. Unstratified salt, Grünsalz formation, with salt fragments, boulders of sandstone, limestone and granitic blocks in greenish-gray clay.
6. Stratified salt, consisting of salt, clay and anhydrite with a southerly dip of 30.°

Occurrence.—The unstratified salt occurs in irregular fragments, as shown in the illustration, some of which are 164 feet thick. They lie in saline clays. To the east this horizon overlies stratified salt, but in the west it extends further and reaches down as far as the borings have been carried.

The salt fragments have often a schistose structure and their composition is about that of the lower beds, but they contain more clay. The fragments have evidently resulted from the dislocation of a previously stratified bed like that of the lower horizon.

The unstratified salt beds contain marine fossils, but no plants. The most abundant species are *Pecten lilli* and *P. denudatus. Nucula* and *Ostrea* are also found.

The stratified salt bed has a miximum thickness of 492 feet.

Fossils.—The fossils in this horrizon, except of *Planorbis,* are all marine and include Foraminifera, Corals, Bryozoa, Echinoderms, Vermes and Crustacea. Among the plant remains that were washed in are fir cones, nuts (*Carya*), fragments of beech and birch wood and a species of palm (*Raphia*). In all in both horizons 274 species have been found in the salt and saline clays.

[121] Windakiewicz, Berg und Huttenmannische Jahrb. der k. k. Bergakademien Wien, vol. 45, 1897, pp. 111-234; plate 3, fig. 1.

[122] Fuchs and De Launay, Traite des Gites Min., p. 511, Fig. 76.

Kinds of Salt.—In the stratified salt bed there are three varieties of salt: *Schibikersalz*, 6-16 feet thick and sometimes more, coarsely crystalline, 99% salt, 1% clay; *Spizasalz*, 65 feet thick, finely granular, grayish, impure, containing quartz sand and is often bituminous; *Grünsalz*, grayish-green, crystalline with inclusions of clay and anhydrite.

The Grünsalz lies between the other two and also forms the salt fragments in the upper horizon. Only the *Schibikersalz* is used for food, the *Spizasalz* is used in chemical factories and the *Grünsalz* is so impure that it is used largely for gobbing.

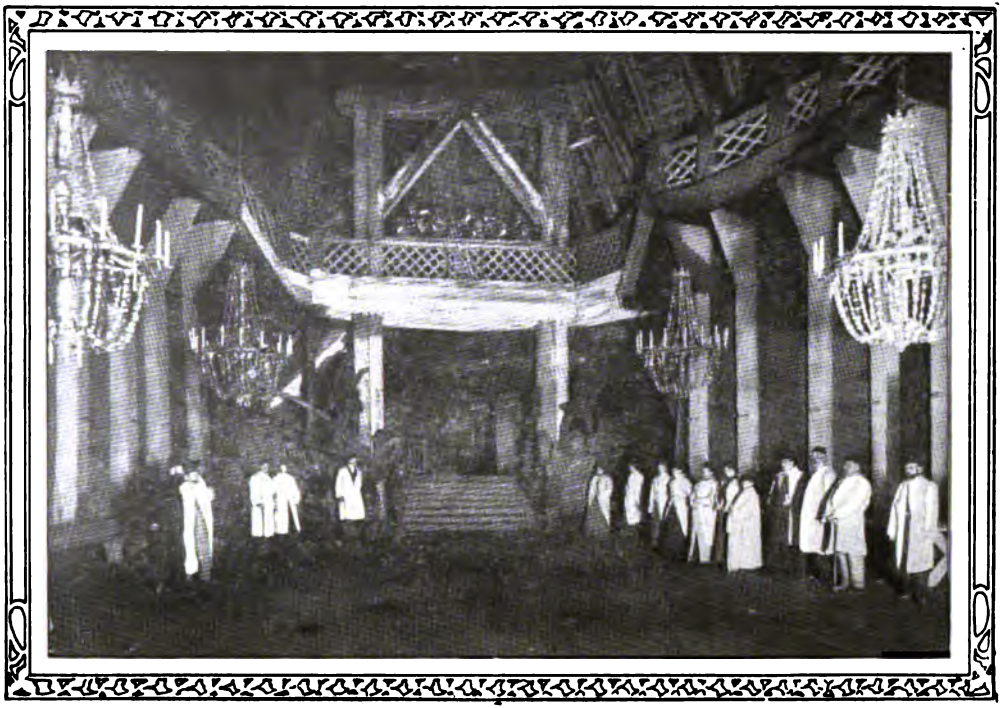
Occasionally very pure crystal salt is found. In olden times this was always sent to the King of Poland, who gave it as presents to his nobility or had it cut into ornaments for his palace. The salt is so very transparent that attempts have been made to make it into mirrors.

Description of the Mine.—The mine of Wieliczka is the largest and most beautiful salt mine in the world. It has been quarried into chambers that lie in seven stories one above the other. The chambers communicate by horizontal passages and the stories are connected by shafts or winding stairs. The depth of the mine is some 984 feet and the lowest chambers are 300 feet below the level of the sea.

The following account of the mine is from the description[123] given by Mr. W. G. Fitzgerald, a New York journalist, who visited the mine in 1905 and secured under circumstances of great difficulty the only set of photographs in existence. Several of these we have reproduced. The policy of the Austrian government in regard to the mine is so secret that the original negatives were not allowed to be kept in this country.

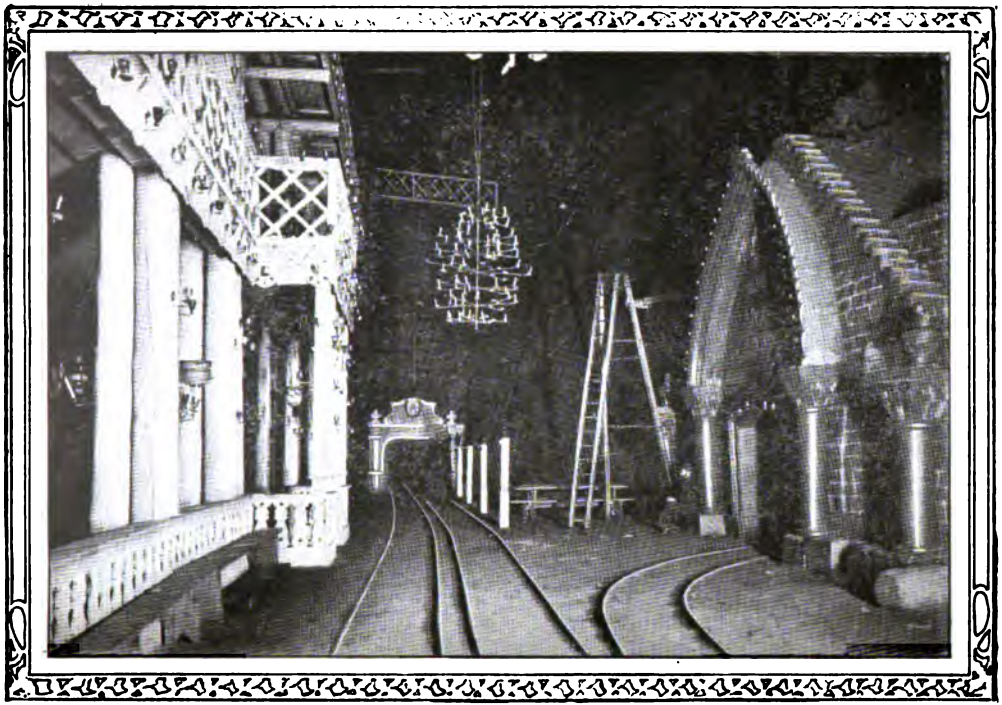
One descends now by an elevator or if one prefers, by the great staircase, one of which was built in honor of a visit of Augustus II, the other for the use of the Austrian Emperor.[124] The first sensation on reaching one of the vast chambers is one almost of terror at the vastness, the thick darkness and the somber echoes. One of the first sights is the great ballroom (see Plate LI) with its venerable pillars and porticoes, galleries

[123] Woman's Home Companion, Oct., 1905, pp. 6-7.
[124] Natural History of Salt. London, 1820.



THE GREAT BALL ROOM IN THE WIELICZKA MINE N. O. FITZ GERALD PHOTO

UNIVERSITY



THE RAILWAY STATION IN THE WIELICZKA MINE N. G. FITZ GERALD PHOTO
(The entire structure is carved from salt)

and stupendous chandeliers all carved with patient art out of glistening salt. One of the chandeliers is 30 feet high and 60 feet in circumference.

Walking hand in hand with one's guide through this enormous ballroom, which dates back to the early part of the eighteenth century, one is told in swift and fluent French of the weird and dazzling functions that have been held there at various times. As, in 1814, at the fete in honor of the Russian Emperor when the walls were festooned with flowers and glittered like diamonds in the brilliant lights and fireworks. A splendid banquet was served and lovely music was played.

In a recess at the extreme end of the great ballroom is a rude but massive throne of greenish salt. This is the throne of the Emperor, Franz Josef.

Leaving the ballroom, one is guided to the Chapel of St. Anthony of Padua, hewn out in the seventeenth century.

Formerly mass was said in the chapel every morning, but now it is only celebrated on the third of July every year.

On the third tier or story of this strange underground city is a railroad station and an excellent restaurant. (See Plate LII). At the railroad station 25 miles of railroad lines from all parts of the mine join together. The station is made entirely of salt. The restaurant is kept open all summer for the benefit of tourists who come from all over the world, but especially from Austria, Russia, Poland and Germany.

Seven hundred feet below the surface of the earth is the great salt lake, a Dead Sea. Over its thick and dark waters visitors are carried in a boat or barge which is guided through the various caverns by ropes and pulleys.

There are more than 1,200 miners. They make a bare living and receive no regular wages, but are paid according to the amount of salt they produce. Some of them work all day long lying on their backs and wielding a pick against the roof—and all for a dollar or so a week. The salt is carried to the railroad in roughly made wheelbarrows.

The miners and the horses which spend all their lives in the mine are seldom or never sick, for the air of the mine is very healthful.

Each workman desiring to return to the upper world is as carefully searched as the Kaffirs on leaving the diamond mines, to make sure that he is not smuggling away any salt.

Mining by means of shafts, as already noted, has been carried on at Wieliczka since 1608. There are at present eight working shafts, of which the deepest is the Kaiser Josef, 984 feet. The others are Franz Josef, Kronprinz Rudolf, Kaizer Franz, Kaiserin Elisabeth, Gorsko, Lays and Bozawola. There are fifteen abandoned shafts.

The salt was formerly mined in cylindrical blocks called *balvans*, weighing 200 to 300 pounds. The name balvan is thought to have been derived from the name of an ancient Sarmatian idol. The salt is now made into blocks weighing 80 or 90 pounds.

Fatal accidents have been caused by the ignition of gas in the mine.

In the Bochnia mines the salt is all *Schibikersalz*, but it is more or less impure and only about 150 yards thick.

KALUSZ.

Salt has been produced at Kalusz, in Galicia, since the fifteenth century. The salt was obtained chiefly from brine pits, of which there were 75 in and near the town.

Potassium Salts.—The rock salt mine is north of Kalusz at Bania, on the Siwka River. As the brines near the shaft were found to contain potassium, an effort was made to find beds of potassium salts. This led to the discovery of kainite,[125] carnallite and sylvite.

The Kalusz salt is Miocene (*Hasclgebirge*). The formation consists of a salt clay containing as much as 50% sodium chloride. Near the upper part potassium salts appear, rarely as carnallite, more frequently as kainite and sylvite.

The salt is mined at three levels from the main shaft at 48, 75 and 108 yards from the surface. In the southeastern field there is also a level at 60 yards. The beds have a uniform strike Owing largely to this decreasing angle of dip, the first level

[125] Tietze, E. Jahrb. Geol. Reichsanst., Wein, vol. 43, 1893, pp. 89-124.

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from the southeast to the northwest and a dip to the southwest, the uppermost at an angle of 40° to 45,° the lowest at 20° to 25.° passes through only a few yards of kainite, the second through 125 yards and the third through 225 yards.[126] (See Plate LIII., A.)

Carnallite occurs only rarely in the kainite bed. Two small masses have been found at the third level, consisting of 41% carnallite and 42% rock salt.

Sylvite is obtained chiefly from the second level.

The total amount of kainite is estimated at about 125,000 cubic yards. In 1895, 2,400,000 pounds of kainite were produced. This is only about 57% pure kainite, while that from Leopoldshall, in Germany is 68%. But in the deeper portion the Kalusz kainite becomes much purer and in the lowest level it is sometimes 95% pure.

A very large proportion of the kainite produced at Kalusz is used in Galicia.

Mode of Formation.—The Kalusz salt deposits were formed in a lagoon, the saline materials being derived either from salt brooks[127] or more probably from the sea through a narrow strait.[128]

In either case the salt beds are regarded as a primary deposit and not secondary, as was earlier thought. The kainite and sylvite are not, as in the Stassfurt basin, products of the carnallite.

THE MINES OF MARMAROS.

The salt deposits of Marmaros only reach the surface in occasional outcrops, but they probably form a continuous underground belt, as the salt springs indicate.

Above the salt are bluish-black clays sometimes 131 feet thick. The depth of the salt is not known, but it has been mined down to 502 feet without losing its purity.

In the Marmaros region there are three groups of mines; one at Szlatina, one at Ronaszk and one at Sznkatak.

126 Furer, Salzbergbau, pp. 158-163.
127 Niedzwiedski, Salzgebirge von Kalusz.
128 Ochsenius, Zeitschr. fur prakt. Geol., 1893, p. 240.

The Szlatina salt mass is 2,177 feet long. The salt has a vertical and horizontal cleavage. The principal chambers are the first, François, which was begun in 1808 and is now 82 feet high and 541 feet long, and the third, Cunegonde and Nicolas.

THE MINES OF TRANSYLVANIA.

The salt-bearing Miocene beds lie in a northeast and southwest direction and are mined at Vizakna, Maros-Ujvar, Parajd, Thorda and Dees. (See Plate XLIX.) The salt, which extends down to unknown depts, occurs as masses in clays. The salt is usually white, but is sometimes gray and in Parajd there is a rare blue, fibrous variety. Peculiar parallel markings occur in the salt caused by lighter and darker layers a few centimeters thick.

Maros-Ujvar.—At Maros-Ujvar the salt mass is egg-shaped and is about 900 yards long and 500 yards wide. It is estimated at 100,000,000 metric tons. A surface view is shown on Plate LIII., B. The vertical bedding of the salt has been explained by the hypotesis that it represents the eroded crest of an anticline, as is shown on Plate LIII., C. The salt is wonderfully pure, being 99% to 100% sodium chloride.

The mine was worked in ancient times, but more modern exploitation began in 1791, where three shafts were sunk 50 to 60 yards in depth. A new field was opened by sinking the Stefania shaft in 1870.[129]

This was the first Hungarian mine to be lighted with electricity.

The salt is under-cut and blasted down and the blocks weighing about 100 pounds are carried in trucks to the shaft and raised to the surface. The small salt is pulverized in mills and packed in 100-pound bags.

A soda-ammonia factory was put in operation in 1896.

This is the largest of the Transylvania mines and employs about 500 workmen.

Dees.—At Dees the salt mass cannot be mined at a greater depth than 50 to 60 yards, because of the infiltration of water

[129] Mines and Minerals, Scranton, vol. 18, 1897-1898, p. 394.

which has honey-combed the salt. Mining seems to have been begun in 1478. The older chambers have a hut or bell-shaped form. One part of the mine has been abandoned, and only the Ferdinand shaft is now in operation.[130]

Parajd.—The salt mass at Parajd is estimated at 950,000,000 metric tons. The salt is under-cut and broken into blocks. The mine is operated only in winter, as the miners are farmers. The same methods are used in the mine at Vizakna.

Thorda.—At Thorda the salt has been mined to a depth of 200 yards. A gallery about 800 yards long leads to the chamber which is now being mined. Some of the chambers are 200 or 300 years old, and are cone-shaped. They are famous for their wonderful echoes. This mine was known to the Romans.

The salt mass is about a mile long and a mile wide.

The miners mark off areas six yards long and break the salt up into blocks weighing about 100 pounds.

At Thorda and Maros-Ujvar a few foraminifera have been found identical with species from Wieliczka. No other traces of organic life have been discovered.

MINING METHODS.

The usual method of salt mining in Hungary, Galicia and Transylvania is by hollowing out vast chambers. Up to 1877 these were bell or bottle-shaped or rarely conical, but since then a rectangular shape has been adopted. A longitudinal gallery is first cut out and from it a series of transverse galleries. The salt is under-cut then broken off into blocks by heavy wooden hammers. Some of the chambers have taken 250 to 350 years to complete.

PRODUCTION AND SALE OF SALT.

The salt mines of Austria-Hungary are a monopoly of the government and one of the principal sources of income.

The first cost of salt at present to the consumer in the United States is less than $2 a ton; in Austria-Hungary it is over $30 a ton. Thus while furnishing less than 5% of the world's total production the salt of Austria-Hungary amounts to about 40%

130 Furer, Salzbergbau, p. 265.
131 Min. Res. of the United States for 1906.
132 End. and Min. Journ., March 24, 1904.

of the total value. In 1905 Austria-Hungary produced 609,572 short tons of salt.[131]

Salt briquettes, for export to tropical countries, are being made in Austria by the Müller press. At the Aussee salt mine a plant was lately installed to turn out in 24 hours 40,000 to 45,000 briquettes, weighing 2 pounds each and containing not more than 1% of moisture. The process consists in subjecting loose salt to a hydraulic pressure of 200 atmospheres.[132]

The Balkan Peninsula.

GEOLOGICAL OCCURRENCE.

The Miocene salt deposits which are mined in Transylvania and Galicia continue along the eastern and southern slopes of the Carpathians and form a rich salt zone in Roumania.[133] (See Plate XLIX.) Thus the Carpathians are completely encircled with saliferous strata. But no rock salt has been discovered on the Balkan Peninsula south of the Danube except in Albania, in western Turkey, and in the southern part of the peninsula salt is obtained only by the evaporation of sea water and brines.

ROUMANIA.

In Roumania in addition to the Miocene salt there are deposits in the Upper Eocene, the Middle and Lower Oligocene and some which appear to be Pliocene.

The salt area is characterized by encrustations of salt in the river channels; by brine and sulphur springs and by masses of salt which form hills. The whole region is extremely sterile.

Lower Tertiary Salt.—These beds follow the Carpathians from Bukowina to the Dimbovita River and then reappear in the valleys of the Arges and the Olt and form several isolated patches westward towards the Danube. (See Plate XLIX.) The salt occurs in various horizons but principally in the Middle and Lower Oligocene. It is generally found in gray, clayey marls along anticlinal folds. A series of salt masses extends from Tirgu-Ocna southward. The mass of salt at Tirgu-Ocna is the most important and the only deposit of the older Tertiary salt mined in Roumania. The salt is characterized by a very small proportion of gypsum.

[131] Mrazec and Teisseyre. Mon. des Int. Petroliferes Roumains Nos. 43-47, 49-51, 1902.

Middle Tertiary Salt..—The Miocene or Middle Tertiary zone of salt also extends from Bukowina to the Dimbovita and from there on interruptedly to the valley of the Oltetu. In the northeastern part of Roumania the Miocene salt beds form the foothills of the Carpathians and the older Tertiary salt beds are parallel but in the high mountains. The Miocene strata are made up of conglomerates, sandstone, marls, gypsum and a dacitic tuff (*palla*).

No fossils have been found except some fragments of wood in the salt and leaf imprints in the sandstones.

The richest salt region is south of the Trotus River. The largest salt masses are those of Slanic and Ocnele-Mari.

Late Tertiary Salt.—Many of the deposits thought to be late Tertiary, Professor Mrazec has found to be overthrust faults of Miocene beds. Others which seem really to be late Miocene and early Pliocene have been found by oil borings in the District of Prahova and at other localities. These salt deposits are chiefly of interest from their close relation to the petroleum.

The Salt Masses—Although there are many beds of salt in Roumania only the salt masses are of economic use, as they can be so much more easily exploited. The exact depth is not known of any of these salt masses and estimates of their size are approximate, but the mass at Ocnele-Mari is thought to be some 330,000,000 metric tons and that at Tirgu-Ocna 264,000,000 tons. More than 50 of these salt masses are known, of which the greater number lie near the curve of the Carpathians.

The stratification of the salt is clearly marked by the alternation of white and grey or blackish beds. This dark color is due to the admixture of a very fine clay, probably of æolian origin. Amber is sometimes found in the salt.

Mining.—Of the 50 salt masses known in Roumania only four are mined.

The salt was formerly mined out in bell-shaped chambers. In 1852, galleries were first made, and the mines are now well equipped with machinery and appliances.

The salt is cut into blocks weighing 20 to 240 pounds, of which the more compact are exported.

Rock salt is ground for use in the fisheries, and at Tirgu-Ocna the ground salt is moistened with water and moulded into cones which on pressure of the hand fall into powder.

In 1903, 90,000 metric tons of salt were produced in Roumania.[134]

Roumanian salt is exported to Servia, Bulgaria and Russia, the largest mount being shipped to Servia.[135]

BULGARIA.

Sea salt is made in many salterns at Anchialos on the southern shores of a large salt lagoon. The product is a grayish salt. The saline of Anchialos produces 10,000 to 15,000 metric tons annually.

The internal revenue tax is 6 lews per 100 okka ($1.20 per 250 pounds).

SERVIA.

Servia is supplied with salt from the neighboring states.

MONTENEGRO.

Domestic salt, made in the sea salines on the Adriatic at Antivari, is largely used in Servia.

GREECE.

Sea salt is made along the Grecian coast and salt is also made from brine springs.

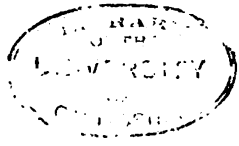
There are salines, on the western coast, in the canal between the island of St. Maura and Greece proper where salt is produced in large quantities. Sea salt is also made on the Island of Crete.

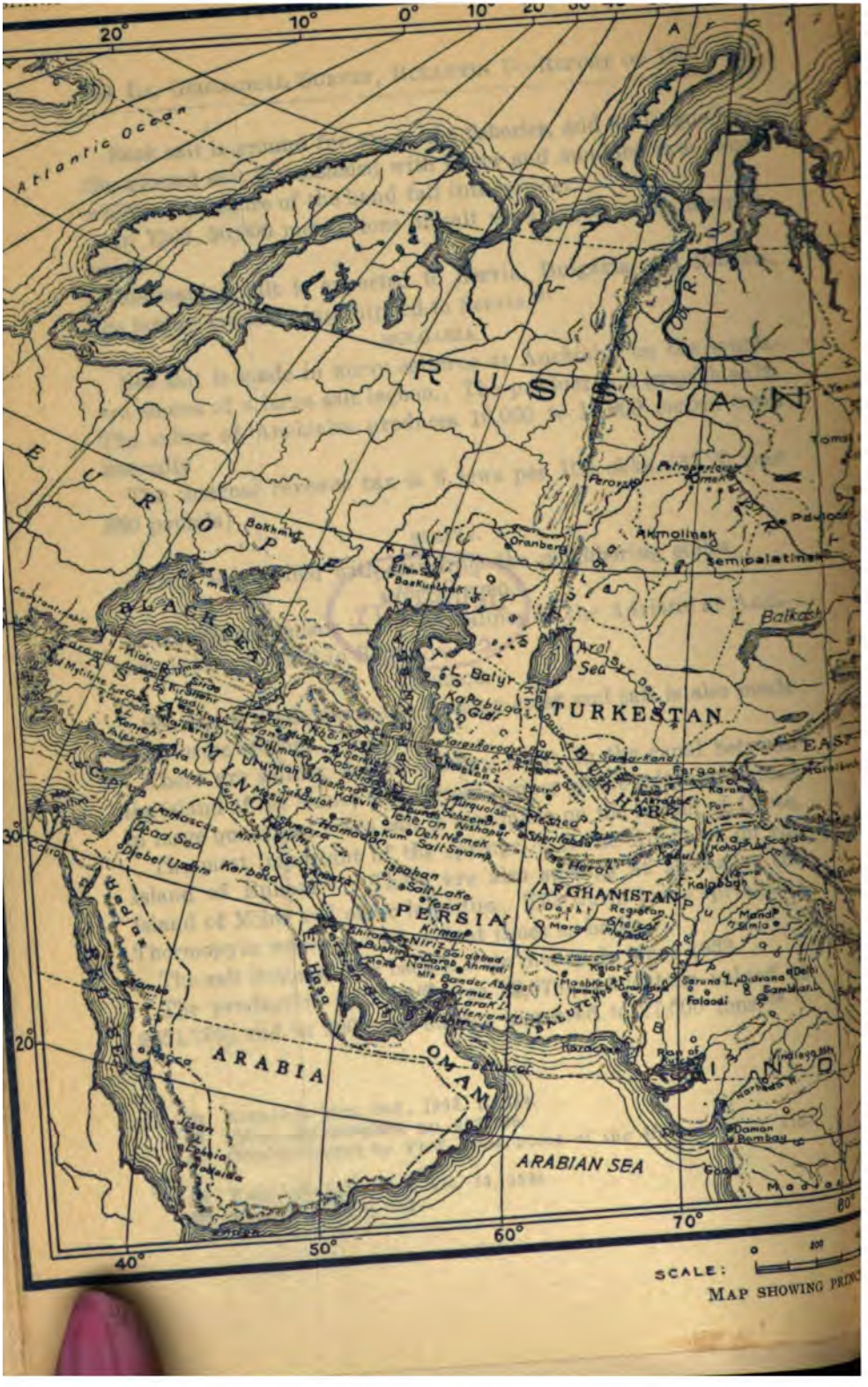
The most important of the springs is at the Adeposos on the Island of Euboea.[137] There are also springs at Methana, the Island of Milos and other localities. The warm brine springs at Thermopylæ were used in ancient times as baths.

The salt industry has been a state monopoly since 1833.

The production in 1900[138] was 23,079 metric tons valued at $351,700, and in 1904 the output increased to 27,000 tons.[139]

134 Rothwell, Min. Ind., 1903, p. 314.
135 Furer, Salzbergbau, pp. 285-286.
137 Communicated by Prof. Metsopulos of the University of Athens.
138 Rothwell, Min. Ind., vol. 13, 1905.
139 Vol. 14, 1906, p. 512.





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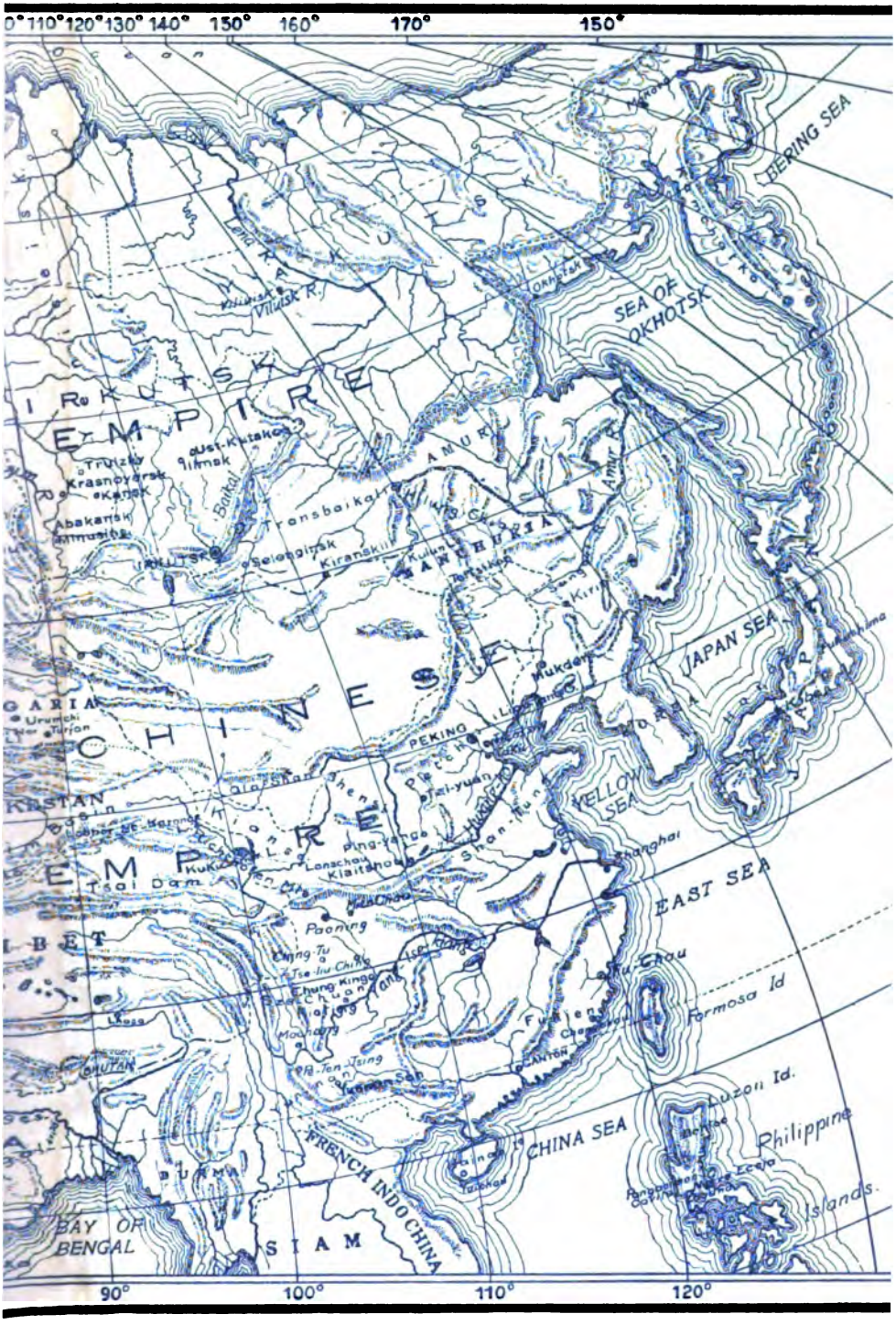

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ALT LOCALITIES OF ASIA

The Russian Empire.

European Russia.

GENERAL IMPORTANCE.

The salt wealth of Russia is unusually large. All Europe could be supplied with salt from Russia alone. Yet the Russian mines are not fully developed and salt is still imported.

Salt in Russia is obtained from sea water, salines, salt lakes and rock salt deposits.

SEA SALT.

Near Odessa, on the shores of the Black Sea, salt is obtained by the evaporation of sea water.

In northern Russia and parts of Siberia salt is made from the sea water by the freezing method. This consists in subjecting the water to a temperature some degrees below the freezing point by which it is resolved into pure water, which is removed as ice, and partly into brine, which remains liquid and is highly saline as a result of concentration. This process is repeated until the maximum salinity is reached. Salt is then easily obtained by slight evaporation.

Salt made by the freezing method is, however, always impure and may contain as much as 15% of sulphate of soda and also chlorides of magnesium and aluminum. Lime is added to avoid the formation of soda and to precipitate the other minerals, but even so, salt made in this manner is injurious to health and difficult to preserve because of its deliquescent character.

SALINES.

There are many salines in Russia, most of which obtain brine from bore holes.

In the Province of Perm salt is made from brines from Upper Permian (Zechstein) beds at Ussoli, Leuvensk, Dediuhine, Beresinsk, and Solikamsk, along the Kama River. Many of these salines have been in operation since the sixth century. In the Province of Volgoda there are salines at Ledenzsk, Totemsk and Seregovsk, which also have their source in saliferous Upper Permian strata.[140]

140 Krusch, P., Zeitschr. fur prakt. Geologie, 1907, pp. 281-283.

In the Province of Archangel salt is obtained from the Devonian in the salines of Vladitchensk, Ousk and Loudsk, where gypsum and naphtha occur with the salt.[141] There are also Devonian salines at Senoska, on the White Sea, and in the Province of Nijni-Novogorod, where there are eight salines.

In the Province of Charkow there are 20 salines.

In south Russia, near Bakhmut, the large Skaramanga saline was opened in 1872.

SALT LAKES.

In Astrakhan there are 1,200 salt swamps and 700 salt lakes.[142] The salinity of the region is so great that in the neighborhood of the lakes a salt dew falls. Elton Lake is the largest. (See Plate LIV.) Its bed is covered with a salt deposit of unknown depth. The name is thought to be a corruption of the Kalmuck name *Altanor*, the golden Lake, from the yellow lustre of the surface of salt at sunset. In 150 years more than 9,000,000 tons have been taken out without making any apparent diminution. Only the under salt beds are used, as the upper, recent beds are bitter.

Lake Baskuntschak has of late become more important in the production of salt than Elton Lake, because since 1882 it has been connected by a railroad with the Volga River. This lake furnishes 15% of the total salt production of Russia, namely, 45,920 tons. The sea floor, which is dry except in spring, is covered with three salt beds with a total depth of 177 feet, of which the upper 32 have been quarried by blasting.[143] The salt is used chiefly in the Volga and Caspian Sea fisheries.

Salt is obtained from 23 other salt lakes in Astrakhan.

Mud Volcanoes.—In the Crimea there are mud volcanoes which eject borax as a product of eruption from the saline beds beneath.[144] In the analysis prior to 1896 borax was not found, 79-81.
but it has been present ever since. The craters of these mud volcanoes are 200 to 1,000 feet high and sometimes 700 feet in diameter.[145]

141 Fuchs and De Launay, Traite des Gites Mineaux, pp. 519-520.
142 Furer, Salzbergbau, p. 275.
143 Traite des Gites Min., 520.
144 Vernadsky and Popoff. Zeitschr. fur prakt. Geol., 1892, pp.
145 Koschkull, Geol. Mag., vol. 6, 1869, p. 121.

ROCK SALT.

There are several lesser rock salt areas in northern and central Russia. One of these extends interruptedly from the Island of Osel, in the Baltic, through Livonia to Lake Ilmen, where it gives rise to the Star Russia springs. Another follows the Volga from Tver to Kasan and a third lies along the Kama and is the source of the brines operated in the salines of Perm.

But the great salt wealth of Russia lies in the southeastern and southern parts of the empire, in the provinces of Orenberg and Astrakhan and in the Donetz Valley at Bakhmut. (See Plate LIV.)

Orenberg.—In the Province of Orenberg one of the largest deposits of salt in the world is at Iletzkaia-Zachtita, 40 miles south of the city of Orenberg. It is very near the Asiatic boundary.[146]

The area of the salt deposit is estimated at one square mile. The depth has been found by boring to exceed 500 feet. At that point the boring was stopped on account of the extreme hardness of the salt. Through the entire depth there was pure rock salt, with very rare and thin beds of gypsum and red clay.[147] The surface is simply scraped to remove the dirt and the salt is then marked out like ice for cutting. The deposit contains more than 150,000,000 tons of salt.[148]

Kirghiz Steppes.—In the Province of Astrakhan, along the lower Volga, there are the remarkable salt deposits of the western Kirghiz Steppes. The steppes are covered with the reddish, sandy, gypsiferous marls which contain recent shells such as are now found in the neighboring Black and Caspian seas. Salt rain is said to fall in the neighborhood of the Caspian Sea, although its waters are much less salty than those of the British Channel.[149] The district is exertmely sterile and very sparsely inhabited. The salt occurs in irregular masses. It is mined in open quarries by side cutting, and the lozenge-shaped blocks are

146 Eng. and Min. Jour., March 7, 1903, p. 373.

147 Harper's Magazine, vol. 76, 1888, pp. 904-910.

148 P. Krusch, "Nutzbaren Lagerstatten Russlands," Zeitschr. fur prakt. Geologie, 1897, pp. 281-283.

149 Strangways, "Geology of Russia." Trans. Geol. Soc. London, 2d ser., vol. 1, 1824, p. 37.

then jarred loose and dislodged with heavy beams of wood. The salt is so pure that it is simply pounded up for use and needs no further preparation.

Bakhmut.—In the Donetz River valley, in south Russia, salt is found at Bakhmut and in other localities. The salt all lies in a Permian trough. The formation consists of yellow clays, and clayey marls, with dolomite beds. The clays contain gypsum, anhydrite, and rock salt.

At Bakhmut borings have been made passing through nine salt layers with a combined thickness of about 328 feet.[150] The upper two are thought to belong to the Upper Permian, while the seven lower beds, which are in the dolomite horizon, belong to the Lower Permian.

The salt industry at Bakhmut was begun only in 1876 and in 1893 the production was 81% of the total rock salt production, namely, 237,914 metric tons.

It is quite probable that the salt deposit of Bakhmut divides about 10 versts north of the city, one part going east toward Donetz, the other, which has been traced by borings, following a westerly course.[151]

Caucasus Mountains.—In the Caucasus Mountains there are extensive rock salt deposits of Tertiary age. Very ancient workings have been found, and in them Koschkull[152] discovered hundreds of stone implements which evidently had been used as mining tools.

Transcaucasia.—In Transcaucasia there are rock salt deposits at Kulp, Nakhitschewan, Sustinsk, Kagysman, Olti and Ordubad.

Salt is also made by the evaporation of the water of the salt lakes in the Caucasus.

150 Macco, "Excursion nach den Donetzbecken," Zeitschr. fur prakt. Geologie, pp. 134-135.

151 A. Monseau, "La formation permienne dans le Bassin du Dunetz," Rev. Univ. des Mines, 3d ser., vol. 41, pp. 155-195.

152 "Geol. Notes on the Caucasus," Geol. Mag., vol. 6, 1869, p. 121.

Asiatic Russia.[153-155]

SOURCES OF SALT SUPPLY.

The salt produced in Russia's Asiatic possessions is derived principally from numerous salt lakes, in which the Province of Omsk and the Transcaspian district are especially rich. (See Plate LIV.)

There are many rock salt deposits in south central Asia and in the Province of Yakutsk which might afford a large source of supply, but they are very often in outlying districts, where the markets are distant and transportation difficult, so that the amount produced in them is as yet small.

Salt is also made by the artificial evaporation of brine principally in eastern Siberia, especially in the provinces of Irkutsk and Yeneseisk.

The average production for Central Asia between 1894 and 1903 was 86,447 metric tons per annum. The yearly average for Siberia and Amur in the same time was 30,850 tons. Thus the total yearly average for all Asiatic Russia from 1894 to 1903 is 117,297 tons.

THE TRANSCASPIAN DISTRICT.

Lying along the shores of the Caspian and on the extensive steppes to the eastward are a number of salt lakes, many of which are salt producers. Salt is also obtained from Karabugas Bay, in the Caspian Sea. Several rock salt deposits are found, one of which produces more than one-half of the total output of the district.

SALT LAKES.

Among the most productive salt lakes east of the shores of the Caspian are Batyr, Karakul and Kaundy lakes; Kuli and Karababa lakes, near Krasnovodsk; a lake near Merv in which a four-inch layer of salt is worked by the native tribes; a lake on the Usboj River (the old bed of the Oxus), on the Transcaspian Railroad; a number of lakes in the Turcoman desert and shallow

153 For a complete account of salt in Asiatic Russia see Das Salz, von Buschman, pt. 2, 1906, pp. 118-142.

154 Zeitschr. fur prakt. Geologie, vol. 5, 1897, pp. 282, 368; vol. 7, 1899, p. 55; vol. 2, 1894, p. 39; vol. 11, 1903, pp. 33, 401-413, with map; vol. 13, 1905, p. 65 .

155 Rec. Geol. Surv. India, vol. 20, p. 100.

lakes northwest of Akrobot from which salt was formerly obtained by the Turcomen.

KARABUGAS BAY.[156-157]

An important deposit of sodium sulphate is formed under the waters of this shallow bay. The sheet of water, which is nearly 6,600 square miles in area, is not more than 50 feet in depth at its deepest point and is connected with the Caspian by a very narrow neck of water. The dry climate and prevailing dry winds cause a very great loss of water by evaporation in the bay and this is replaced by a constant in-flow of water from the Caspian Sea. The water is concentrated in this way from 1°.3 to 2°.2 Beaumé. Baer has estimated that 350,000 tons of salts are carried into the bay from the Caspian every day. The ratio of sodium chloride to magnesium sulphate in the Caspian is very high, being 2.1. When brine of such chemical composition is concentrated a reaction takes place resulting in the formation of Na_2SO_4 and $MgCL_2$. At a temperature of 0° C. a 5% solution of Na_2SO_4 will precipitate, while $MgCL_2$ is more soluble than Na_2SO_4 will precipitate, while $MgCl_2$ is more soluble than deposited in the middle of the bay where the concentration is greatest. More salt is deposited in winter when the water freezes than during the summer. The deposit, which is over a foot thick, overlies a more extensive bed of gypsum and is estimated to be 1,350 square miles in area, and to contain one billion metric tons of salt.

ROCK SALT.

The most important deposits of rock salt in the Transcaspian district are found on Cheleken Island in the Caspian Sea, and at Balla Igshem on the Transcaspian Railroad.

Cheleken Island.—The salt on this island lies at a depth of one to four feet from the surface and is overlain by a layer of white sand. The amount of salt is estimated at 328,000 tons, of which 75% is a pure, white salt.

The production from this island between 1890 and 1898 varied from 8,177 to 17,112 tons.

156 Zeitschr. fur prakt. Geol., vol. 5 ,1897, pp. 282, 368; vol. 6, 1898, pp. 26-27; vol. 11, 1903, p. 33.

157 Le Sel, Larbaletrier, 1900, pp. 31, 32.

Balla Igshem.—This deposit covers a little more than 13 square miles and is estimated to contain 3,603,600 tons of salt. In 1897, 334 tons were produced.

TURKESTAN, BOKHARA AND KHIVA.

Khiva and the northern and eastern portion of the Transcaspian district form part of a great steppe of which the surface soil contains a large proportion of salt, and the soil in northern Bokhara is of a similar nature. There are few salt lakes in this region, but a great many rock salt deposits occur.

SALT LAKES.

Near the city of Bokhara there are salt lakes, but no salt is produced from them. There are several on the Pamir plateau, of which the largest, Lake Karakul, lies some 13,100 feet above the sea. Salt is obtained from lakes in Ferghana, Smarkand and Syr Daria.

ROCK SALT.

Province of Bokhara.—Southeast of the city of Bokhara, on the right bank of the Amu Daria River and two miles from it is a bed of rock salt five miles long. The salt is worked though black and is of poor quality. Thick beds of salt are found beyond Shurab, overlying red clays and rock salt is mined near the town of Hissar. Other extensive deposits occur in the mountains of southern and eastern Bokhara. A deposit is also reported about 40 miles north of Kwaja Salar, and in 1888 rock salt was discovered in Ferghana, 220 miles from Smarkand. The latter is estimated to contain 3,276,000 tons of a very pure salt, but the distance from inhabited regions and lines of travel has prevented its systematic development.

Central Government of Omsk.—This area, containing the districts of Turgai, Uralsk, Amolinsk, and Semipolatinsk, includes the eastern part of the great Kirghiz Steppes, on which numerous small lakes are found. The surface soil is made up of calcerous, oligoclase sands.

A number of the lakes in the northern portion of this part of the steppes are fresh water, but the proportion of salt lakes increases towards the south, where some contain water only during the rainy season. In all there are some 700 brackish and salt

lakes in this province, and all the salt produced is derived entirely from them. Some of these lakes furnish a very pure sodium chloride, while others contain a mixture of various salts, and a few produce sodium sulphate almost entirely.

Three of the most important lakes are owned by the government. The first of these lies about twelve miles north of Pavlodar, on the Irtysh River.

The second lake belonging to the government is also north of Pavlodar and the third near Semipalatinsk.

Salt from Lake Inderkish is supplied from a small brook only six feet wide and about a foot and a half deep, which carries 600,000 tons of salt into the lake every year.

The salt obtained from this and neighboring salt lakes is used to cure fish in the Ural fisheries.

In all these lakes the salt is removed from the bottom and dragged to shore, where it is thrown into heaps and washed or simply left to dry. The more soluble potassium salts drain off and the sand drops off when the salt is dry. It is then ready for shipment. The salt near the Irtysh River is transported to boats in two-wheeled carts drawn by horses or camels.

According to official figures the average production in the central government of Omsk from 1894 to 1903 has been 44,000 tons per year.

SIBERIA.

WEST SIBERIA.

In the district of Barnaul in southern Tomsk, salt is obtained from two groups of salt lakes, the Borovaia and the Burlinsk, which include about forty lakes.

Between 1894 and 1903 the production of salt in western Siberia averaged 18,000 tons a year.

EAST SIBERIA.

Salt is obtained in southern Yeneseisk from various lakes and brine springs. The lake beds are in Devonian rocks and the brines flow partly from the Devonian and partly from the Cambro-Silurian.

Brine Springs.—Near Kansk are the salines of Tumanchelskiy and Troizky. At the former brine of 4.5° Baumé is obtained from 19-foot wells.

Salt Lakes.—Salt is produced from Lakes Altai, Kisil Kul and Beisk, which lie on the steppe between the Yenesei River and its tributary, the Beja.

Lake Altai.—This circular lake, 3,000 feet in diameter, contains a layer of very hard salt about nine inches thick. The water of the lake is rich in sodium sulphate, so that common salt is made only in autumn and winter, when a great deal of the sodium sulphate separates out on account of the low temperature of the water. Part of the bottom crust, somewhat decomposed, washes out on shore and is gathered and sold to the glass factories.

Lake Kisul Kul.—This lake is southeast of Lake Altai and about 37 miles from Minussinsk. Its bed is extremely shallow and only partly covered with water. The salt is manufactuerd from a brine obtained from five 33-foot wells on its outer edges. The work of evaporating the brine in large iron pans or kettles goes on throughout the year. Lately the production has been 1,500 tons a year. The brines from the different wells have the same chemical composition and register from 9° to 12° Beaumé. The following is an analysis of the brine:

Taste—Very salty and a little bitter.

Color—Fresh from ground, yellowish or milky; later clear.

Spec. Gr. at 15° C., 1.0858.

Chemical composition (in 1,000 parts of water):

Magnesium chloride	.0091
Calcium carbonate	.2595
Calcium sulphate	2.1704
Magnesium sulphate	10.0189
Potassium sulphate	.8307
Sodium sulphate	8.6267
Sodium chloride	86.5800
Sodium carbonate	.1364
Ferric oxide	.0022
Anhydride of silica	.0450
Ammonia	Trace
Lithium	Trace

Lake Beisk.—This lake is ten miles northwest of Kisul Kul Lake and is about 3,000 feet long and half that in width. Its waters contain a very large proportion of sodium sulphate

(Na_2SO_4), and salt can be made during the cold season. In dry years as much as 983 tons have been produced from this lake.

In 1897, Lakes Altai, Kisul Kul and Beisk produced together 1,980 tons of salt.

A bed of rock salt is said to occur at Isankaef, southwest of Krasnoyarsk.

Province of Irkutsk.—In this province all the salt is made from brines derived from lower Devonian beds. There are three salines. One is at Ussolje, on the left bank of the Angara, about 50 miles from the city of Irkutsk, with one well nearly 1,000 feet deep and several from 13 to 35 feet deep. The second is at Ustkutsk, on the Kuta River, about two miles from where it joins the Lena. The third saline is at Ilimsk, on the Ilma River.

In some of these salines the brine is concentrated in the winter by the freezing method.

From 1894 to 1903 the brine springs of the province of Irkutsk produced 7,800 tons of salt per annum.

Province of Yakutsk.—Important rock salt deposits occur near Viliuisk, in the Province of Yakutsk. The region is, however, so remote and thinly populated that the beds have not as yet been developed to any extent.

The largest of the outcrops, 1,050 feet long and 350 feet wide, is on the right bank of the Kempdei River.

Provinces of Transbaikalia and Amur.—Salt is made in these provinces from a few salt lakes and from sea water along the shores of the Sea of Okhotsk.

Lake Borzinsky produces annually 2,460 to 3,280 tons, and a very pure salt, 99.73% sodium chloride, is obtained from Lake Wirsan. At Selenginsk, south of Lake Baikal, 66 to 115 tons are produced, and at Kiransk, near the Chinese border, 328 tons are made from brine wells in the bottoms of salt lakes.

Along the shores of the Sea of Okhotsk flakes of sea ice are blown on land. The water separates out by evaporation and a deposit of salt known as rassol is left, which is scraped up by

the fishermen. Rassol is composed of:

Sodium chloride	77.60
Sodium sulphate	13.60
Aluminum chloride	6.23
Calcium chloride	.94
Magnesium chloride	1.66

It is whitish in color, of a bitter taste, and has strong medicinal qualities. The fishermen on the coast very seldom use any other salt. Indeed, there is no supply of salt in the far northeastern region except this sea salt.

The natives in Kamchatka, Okhotsk and Markova use salt for preserving fish, but do not take any salt otherwise with their food.

IMPORTATION AND EXPORTATION.

The total production of salt in the Russian Empire in 1903 was 1,828,646 short tons, valued at $3,652,074.[158]

Japan.[159]

Japan's salt production comes mainly from sea water. Brine springs from which small quantities are made occur at several localities. According to Fürer there are also rock salt mines in Japan. He states that the most important are in the provinces of Iwashiro and Echigo.

SEA SALT.

Sea salt is made along the coast of all the larger islands, especially on the Island of Hondu on the shores west of the city of Kobe, and on the southern island of Formosa.

As a rule the sand method is used on the salt farms. That is, the floor of the saltern is made perfectly level and covered with an even layer of clay that is packed down and covered with a thick bed of coarse sand, which is kept loose by frequent raking. The sand is irrigated with sea water, led into the saltern through narrow ditches, and after this evaporates the process is repeated until the sand has become thoroughly saturated with salt. The sand is then put in filters, sea water is poured on and the brine which filters through is evaporated in pans over charcoal fires. The salt so made is grayish and contains 8% to 12% of water and only 80% to 90% of sodium chloride. Both

158 Min. Res. of the U. S. for 1906. Advance chapter on Salt by A. T. Coons, p. 14.

159 Von Buschman, Das Salz, pt. 2, pp. 86-106.

Japanese and Chinese salt is very inferior to the sea salt of the Adriatic.

In some salterns salt is made by the direct evaporation of sea water in the sun and wind. At Nagasaka 990 metric tons are made by one company per year direct by evaporation, and this salt is of a better grade.

More than 100,000 persons are employed in the sea salines of Japan exclusive of Formosa.

A great deal of sea salt is made along the western coast of Formosa, as almost all its 190 miles of shore are suited to that industry. There were 1,250 salt farms on the island in 1903, covering some 80,000 acres, but it is estimated that 500,000 acres might be used for salt making. Two systems are used—the old, which is very like the sand method used on the other island, and the new, in which each farm has two evaporating pans and one crystallizing pan, all having marl or clay bottoms. Only four or five men are required to operate a farm and each laborer produces on an average of 11 tons of salt. The working season lasts from 140 to 250 days a year.

The output as given below is for the season from May to March:

1899-1900	1900-1901	1901-1902	1902-1903
11,038	35,287	50,000	61,923

Analyses of sea salt from three localities in Formosa are given below:

	1.	2.	3.
Sodium chloride	95.779	90.180	97.100
Potassium chloride	trace	trace	trace
Magnesium chloride	trace	1.452	1.205
Magnesium sulphate	.123	.678	.000
Calcium sulphate	.116	3.681	.076
Calcium chloride	.000	.000	.357
Insoluble	4.600	3.490	.794

BRINE SALT.

The most productive brine springs are at Takashima-Mura (Sagaken), where the government has established steam pumps to raise the brine. About 29,870 bushels are produced yearly.

PRODUCTION.

Japan produced 773,776 short tons of salt in 1904, valued at $4,852,049.

By an act passed in June, 1905, the salt industry became a government monopoly and all salt produced is delivered to the government at a fixed price. The salt is of five grades, ranging from over 90% to 75% sodium chloride. No salt with a lower percentage is accepted.

IMPORTATION AND EXPORTATION.

The policy now is to discourage the importation of salt and only the government or persons directly authorized are allowed to import it. The production in 1905 was so low on account of the war, that salt had to be brought in from China.

Salt is exported from Japan chiefly to Siberia and Korea, and in smaller quantities to the Philippines and Australia.

Philippine Islands.[160-162]

Rock salt deposits and brine springs occur in the Philippines, but, as one would expect, most of the salt is made from sea water. Glauber salt is said to be made by crude processes on the islands.

ROCK SALT.

On the island of Luzon rock salt occurs in the mountains of Blanco and Bamban in Nueva Ecija Province, and at Calamba, in Laguna Province. In the Province of Pangasiman, northwest of Manila, the salt beds are so pure that the province has received its name from the salt industry and means "a place where salt is made." Rock salt is also found further south, on the Island of Mindanao, in the Province of Suriago.

BRINE SALT.

Salt is made from brine springs in northern Luzon at Mainit, in the Province of Bontoc.

SEA SALT.

Sea salt is made in small quantities all over the Philippine Islands and those of the Sulu Archipelago southwest of Mindanao But the largest amounts are made in the coast towns of Cavite Province, south of Manila, and exported to that city, and

160 Von Buschman, Das Salz, pt. 2.
161 Textile Colorist, Phila., vol. 26, p. 134.
162 Becker. Philippine Commission, vol. 3, 1901, paper No. 4, p. 236.

sea salt is an important product of the Island of Mactan, off Opon, on the eastern coast of Cebu.

Since the American occupation all restrictions on the manufacture of salt have been withdrawn. There are no estimates of the amount produced.

The East Indies.

The East Indies, like the rest of tropical Asia, depend almost entirely on the ocean for their salt supply. No rock salt deposits have been discovered except in the Portuguese part of the Island of Timor. Brine springs occur on various parts of Java; in southeastern Sumatra (Palembang) and in western Borneo.

SEA SALT.

There are sea salines on the northeastern coast of Java and the Island of Madura near that shore, and on the southern coast of Java in the vicinity of Surakarta. Sea salt is made on Sumatra in the northwestern part, near Achim; on the islands along the western coast and off the eastern coast on the group of small islands southeast of Singapore. On Celebes there are sea salines in the north, near Menado, and in the south near Mecassar.

BRINES AND MUD VOLCANOES.

On the Island of Java salt is also made from brine springs, which flow from Miocene beds and usually contain iodine and bromide salts, as well as sodium chloride. Many of these brines contain petroleum and gas. The most striking are those of Grobogan, northeast of the city of Samarang, in north central Java. According to Karsten, the brines which are associated with mud volcanoes are in a limestone formation that forms a circular plain half a mile in extent. The brine springs occur in large numbers and broil from fissures in the rocks. The water is strongly saline and gives very good salt on evaporation. In the center of the limestone region is a remarkable volcanic phenomenon. On approaching this from a distance one sees a dense cloud of steam that at intervals of several seconds rises and then disappears. This is accompanied by a roar like distant thunder. Nearer by one perceives a hemispherical mass about 16 feet in diameter, composed of black mud saturated with salt

[63] Von Ruschman, Das Salz, vol. 2, pp. 107-117.

water. This mass is regularly raised to a height of 30 feet by an underground force and then explodes with a deafening roar and globular masses of the black mud are thrown in every direction. After an interval of two to four seconds the mass of mud is again raised and again torn to pieces by an explosion. For many years the natives have obtained salt by evaporating the brines ejected by these mud volcanoes. The salt water is led away in ditches to the outskirts of the region and is then evaporated. Some 200 metric tons are made annually.

Small mud volcanoes with pools of salt water are also found on Ceram, one of the Spice Islands.

PRODUCTION.

Salt making is a government monopoly in the greater part of the Dutch East Indies and is forbidden to private persons in all districts under the control of this monopoly except Grobogane in Java and on Madura. On the latter island there are three salines along the southern coast which are owned by the natives, who deliver their salt to the government at a fixed price ($2.39 per ton). The salt is gray, coarse and highly hygroscopic. It contains 5-6% of water and has to lie three or four years before it is fit for transportation, and even then the loss due to handling is great. To facilitate transportation, since 1891, a great deal of the salt has been packed in the form of dense briquettes covered with waxed paper. The briquettes weigh from one-third of a pound to 27 pounds and are easily handled, but they deteriorate with time. Madura produces an average of 83,398 metric tons of salt yearly.

The Grobogan brines are worked by natives, who pay a tax of 20 per cent of their income for the privilege. They are not allowed to export the salt from the district.

CHINESE EMPIRE.

CHINA PROPER.

In China[164] salt is made from sea water on the coast and from brines. The latter are obtained from springs and deep wells and by leaching out the salt-bearing deposits of lossos in inland basins.

[164] Von Buschman, Das Salz, vol. 2, pp. 3-33.

SEA SALT.

Sea salt is made in all the coast provinces of China, but especially in Fukien, Shantung and Pechili (see Plate LIV). In Fukien the most important salines are at Fu Chau, Changchau and Changyin; in Shantung there are 2,920 salterns and on the Sea of Pechili there are the important salines of Taku. This city and Tientsin are the great salt markets of the Yellow Sea. There are also large salines south of Canton at Yaichau, on the Island of Hainan.

BRINE FROM WELLS.

In the southern part of China proper brine is obtained from deep wells in the provinces of Sz-chuan and Yunnan.

Sz-chuan.—Near Kiating the salines are said to cover an area ten miles long by four or five miles wide and to have wells from 1,500 to 1,800 feet deep. Between the towns of Mienchau, Paunning and Hochan are the Kialing and Tz-lin-ching salines.

The following description is from Mr. Upcraft's interesting account of his visit to the Sz-chuan mines in 1900. He says that the salt wells of Sz-chuan are one of the sights as well as one of the important industries of the province. After journeying many days on an uncouth-looking houseboat through the wild gorges and canyons of the upper Yangtze one reaches a more or less open country and the traveler catches sight of a group of straw shanties along the river's edge, over which a cloud of steam is always hovering. This is the first indication of the salt trade of Sz-chuan. During the high water in summer and autumn these salt springs are overflowing, but when the river subsides a mushroom town of straw shacks grows up, the evaporating pans are set in mud furnaces and the work goes on continuously till the next high water submerges the springs and drives the salt boilers off.

But a month's journey west is yet needed before the main seat of the salt industry is reached at Tz-lin-ching—a "self-

[85] "Brine and Oil Wells in Western China," by J. V. Burn Murdock. Trans. Inst. Mining and Metallurgy, 1900-1901, vol. 9, pp. 362-365, with two plates.

[86] "Chinese Mines and Miners" by A. Reid. Inst. Mining Engineers vol. 23, 1901-2, p. 34

flowing well"—where a large and thriving but squalid town exists because of salt wells. How and when these springs were discovered the Chinese do not say. They have existed for a long time and become a part of the things that are.

At Tz-lin-ching the well proper is a small opening of a few inches in diameter, over which a stone is placed, covering the true mouth of the well. Above this rises a crude derrick with a clumsy, clattering wheel at the top; a hamper rope passes over the wheel and is attached to a long bamboo tube that goes down into the well. The other end of the rope is carried into an adjoining shed and attached to a heavy wooden cylinder 50 or 60 feet in circumference, resting on a vertical axis. When the tube has been lowered into the well four lumbering water buffaloes are hitched to the cylinder and lashed to a run, the cylinder is started, and soon the rope is all wound in, leaving the bamboo tube filled with brine dangling in the air. A man seizes the tube, holds its lower end over a tub or reservoir, thrusts an iron pole into the tube and opens a valve, when several gallons of dirty black water rush out. The tube is then released, the cylinder set free and the rope rapidly paid out till the tube reaches the bottom, when the process is repeated.

The brine is conducted to the evaporating sheds through bamboo tubes plastered with lime. At certain points in Tz-lin-ching natural gas has been struck. The gas is conducted by straw-braided, lime-plastered bamboo tubes to rude sheds, where it is distributed under rows of thick iron pans containing the brine and the work of evaporating goes on day and night, because the Chinese have found no way of regulating the supply of gas and no method of storage is known to them.

The salt is a hard, dirty looking mass when taken from the pans, but the Chinese are proud of the product of their wells and assert that its power of salting is much greater than the white, foreign salt.

The brine-bearing area lies in an anticlinal axis which trends northeast to southwest and covers about 90 square miles.

157 "The Salt Wells of Sze Chuen, China," by W. M. Upcraft, Engineering and Mining Journal, vol. 69, 1900, p. 525, four plates.

The following is a section of this field:[168]

	Feet.	Feet.
Yellow Territory sandtones	125 to	328
Jurassic beds		656
Bituminous springs, Liassic sandstone, gas springs		230
Variegated marls and Permian limestone with salt springs, 12-15 saturation		1,968
Silurian carbonaceous sandstones and Cambrian schists with salt springs, 15 to 28 saturation and the principal gas springs	3,050	3,068

Different estimates are given by authors of the depth at which the brine lies and the vertical distance through which it is distributed. According to von Buschman it lies at a depth of 1,480 to 2,360 feet. Another estimate is 500 to 3,500 feet below the surface.

The life of a good brine well is said to be from 20 to 50 years.

When a site for a salt well has been selected, after much incantation and ceremony on the part of the hired geomancer, a framework of heavy planking is built. The method of well boring is then in many respects very similar to that used in drilling with cable tools in the United States. The boring is done by the percussion method, using an iron drill and bamboo rods. A beam suspended over a wooden framework and with one end attached to the rods at the head of the hole is used as a lever. The drill and rods are lifted and allowed to drop by half a dozen men stepping on a platform attached to the long end of the beam and then stepping off simultaneously when it has sunk as far as it will go. The drill is turned meanwhile by a man at the head of the well. By this method wells over 3,000 feet deep have been drilled. These wells take from four to forty years to complete.

The brine is led through bamboo tubes to thick iron pans, where it is evaporated over gas flames, the gas coming from wells in the field.

Two qualities of salt are produced—a loose, rather white product taken from the pan while evaporation is going on, and

168 "Traite des Gites Mineraux et Metalliferes," Fuchs and De Launay, vol. 1, p. 473, Paris, 1893.

a hard black cake of bitter taste, produced by complete evaporation of the mother liquor.

The annual output is estimated at somewhat less than 200,000 tons, but it must undergo considerable variation, from the difference in the estimates given by differed authors. The area has been worked for from 1,600 to 2,000 years.

Province of Yunnan.—Many brine-bearing horizons have been

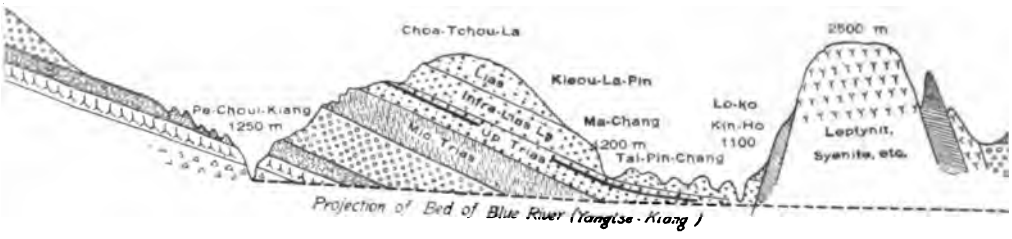


Fig. 26.—The Ma Chang Syncline, China. An Important Brine-Producing region. (Laclere, Ann. des Mines, vol. 22, pt. 2, 1901.

penetrated within the great Ma Chang syncline in the province of Yunnan.[169]

Except at Pe-Jen-Tsin in the deepest part of the syncline the brines are rather weak. This is probably due to local leaching. Deeper wells into the upper Permian which is protected by thick Mesozoic deposits, should give better results.

The principal salt bearing localities are: Galin-Tcheou, northwest of Yunnan-sen; Hetsin and Heoutsin, both northeast of Lang Tsin.

At Lang Tsin the brine gathers in rectilinear chambers dug in the hillside.

169 "Etude Geologique et Miniere des Provinces Chinoises voisines du Tonkin," by M. A. Leclere, Annales des Mines, vol. xx, 1901, part 2, p. 446, with Geol. map and section. Review of the above in Zeitschr. fur Praktische Geologie, vol. 2, 1903, p. 162.

At Hetsin a number of square shafts are used, the largest of which is 300 feet deep and 6 feet 6 inches on the side. The brine is hauled out of the shafts in buffalo hide sacks. The hauling is done by a windlass and cable, the windlass being turned by four men at the top of the shaft.

Shensi and Kansu Provinces.—Brine springs in Shensi produce a good grade of white salt and an inferior quality of red salt.

In Kansu salt is made from brine springs near Lan-Chau. The brine is apparently from Carboniferous sandstone. Salt is made from several small salt lakes on the western slopes of the Richthofen Mountains.

Potassium Salts.—Kieserite ($MgSO_4+H_2O$) is made by leaching out the red clays at the military station of Jutjawan not far from Lan-Chau. No common salt is found in this brine. Charcoal and ashes are added to the liquid while it is being evaporated, and these substances thoroughly saturated with salt, form hard masses which are broken up and sold for soap.

LOESS DEPOSITS.

Salts are obtained from many of the interior Loess basins[170] of the Province of Shansi, west of Pekin.

LUTSUM LAKE.

A better grade of salt than that obtained from the Loess deposits is made from Lake Lutsum in southern Shansi. Large quantities of salt are produced from this lake.

TIBET.

Tibet consists for the greater part of a high plateau about 13,000 feet above sea level, surrounded by mountains with peaks 20,000 to 23,000 feet high. Most of the rivers are without outlet to the sea and flow into salty inland lakes, which frequently have salt crusts along their shores and in their basins. The crusts vary in composition in different localities, but consist principally of magnesium and sodium sulphate with some sodium chloride, saltpeter and borax. The borax, known as *tinkal*, was early exported from Tibet and a considerable amount comes from there yet. Common salt is made or harvested at a great many

[170] "China," F. von Richthofen, vol. 1, p. 102; vol. 2, pp. 418, 429 447-449, 478.

of the salt lakes of Tibet. Some of the most productive are on the Tsaidam desert, which lies west of Lake Kukunor. In the southern part of this desert is a salt steppe with many salt basins, and in the northern part is Lake Tsaidam, which is 22 miles in circumference. The Mongols dig shallow holes along its shores and obtain salt crusts after the brine has evaporated.

Salt is made by the Chinese government from Lake Dabassunnor, in the Kukunor Mountains. North of these mountains the Mongols scrape up the salt crust on the floor of Lake Serkenor, near Karanor, and barter it for meal in the towns.

There are many salt lakes northwest of Lhasa, one of which has an extensive salt plain at its western end.

Travelers in southern Tibet often mention meeting large caravans of yaks laden with salt. Some of these caravans have as many as 1,200 animals. A great deal of the Tibetan salt is taken through the mountain passes to India.

EAST TURKESTAN AND SUNGARIA.

In the northwestern part of East Turkestan there is said to be a salt mountain near the town of Maralbashi, not far from the Tarim River. Salt springs occur at the western end of the Tarim basin and salt lakes along its lower course. The Lopnor basin, into which the Tarim flows, is a salt swamp and is covered with a salt crust.

MONGOLIA.

In Mongolia the more important lakes are the Gurbunduty, which is about two and a half miles in circumference and has a salt crust from 18 inches to 2 feet thick, and the Dsharati-Dabassu, which lies in the lowest part of the desert of Alashan. This lake is about thirty miles in circumference and contains a layer of salt two to six feet thick on the surface of the basin. The salt is harvested and the thin layer on the surface, which is dusty, is scraped off. It is then washed in water, packed in sacks and transported on camel back. A camel-load is about 350 pounds. The governor of Mongolia gets all the profits from selling the salt and rents his camels for transporting it, taking nine-tenths of all the money the drivers can make.

MANCHURIA.

Salt is made in large quantities from sea water on the shores of the gulf of Liaotung. A crust of inferior salt is formed in Lakes Kulun and Per.

Soda is found on the shores of some of the small lakes, the largest deposit being thirty miles from Tsitsikar. About 164 tons of soda are exported every year.

In Manchuria the salines are leased by the government to private persons, who are kept under strict supervision and pay a fixed sum for the privilege of operating the salines. But in Mongolia, East Turkestan and Tibet the government exercises no control over the salt output.

SIAM AND FRENCH INDO-CHINA.

In Siam many salt springs occur east of longitude 101° east, and north of latitude 15° north.

Salt is made from them at Pitsanuloke, Isan, Udon, Korat and Nakon Nan. The salt varies considerably in composition in different localities. The yearly production is about 5,379 metric tons. In French territory, brine springs are found between Bazac and Pakmoung, in red and grey quartz sandstones.

Sea salt in much larger amounts is made in the coast provinces of Siam, especially at the mouths of the rivers Menam and Tatschin, in the Gulf of Siam and at Meklond, southwest of Bangkok. Sea salt is also made at Hue, on the east coast of French Indo-China, during the dry monsoon season. The output of sea salt in Siam varies considerably, but averages about 52,700 tons a year.

The total production of salt in Siam is about 58,100 tons a year.

INDIA.

GENERAL OCCURENCE AND IMPORTANCE.

Of the salt produced in India about 6 per cent is made from water, on the coast, 11 per cent from rock salt and the rest principally from the brine in salt lakes and springs. A small amount is also made from brine obtained by the lixivation of salty soils, and as a by-product in saltpeter works.

The total production of India in 1905 was 1,336,682 short tons, valued at $2,198,090.

SEA SALT.

Salt is made from ocean water in the presidencies of Bombay and Madras and to a lesser extent in Bengal and Burma.

Bombay Presidency.—Salt is made in Bombay from ocean water at Maurypur, seven miles west of Karachi, in the province of Sind, and in a region within thirty miles of the city of Bombay. The method of winning the salt is very much the same as that followed in the salt works of California and Aden. That is the brine passes through two outer basins before the salt is finally precipitated in the third basin. After precipitation the salt is thrown on the banks of the basin to dry, when the process is considered complete.

Between 1898 and 1903 the average annual output of sea salt in the Bombay Presidency, exclusive of the Maurypur saline, was 285,312 tons (1 ton, 2,204 pounds). About 16,000 tons a year, is also made along the west coast of India in the Portuguese towns of Diu, Damon and Goa.

Madras Presidency.—The numerous salines that once existed in Madras Presidency, along the west coast, south of Bombay, have almost all been abandoned because of the large rainfall. A few still remain in Travancore and Cochin. Along the east coast there are about eighty sea salines or "factories," as they are called, which cover an area of 13,800 acres. The sale is made as in the Bombay salines and the work is all done between April and October.

From 1898 to 1903, the yearly average output for Madras was 313,157 tons. In the year 1903-1904 it was 248,850 tons.

Bengal...Six thousand of the 8,000 tons of sea salt was made at two factories on Chilka Lake, in the district of Orisso, up to the year 1897.

Lower Burma.—Salt is made at several points along the coast of Lower Burma by boiling ocean water.

ROCK SALT.

Rock salt occurs in two regions in the northwestern corner of the Punjab. Of these the series of beds outcropping in the southern escarpment of the Salt Range is perhaps the most important; the other region lies about a score of miles to the northwest of the western end of the Salt Range. Beds of salt are found

in the State of Mandi, in the Himalayas, and there are several other occurrences of minor importance.

THE SALT RANGE.[171]

Location.—This range of mountains (see Plate LV) extends in a general east and west direction, from 71° 30′ east longitude to beyond 73° 30′, and lies between 32° 23′ and 33° 0′ north latitude. It is cut off to the northwest by the valley of the Indus, and to the east and southeast by the Jhilam river.

The southern face forms an escarpment overlooking flat, dry plains. On the northern side the mountains slope gently to the Potwar plateau. On the eastern and western ends the range turns up toward the north. The average height of the range is about 2,000 feet, and the highest peak is 5,000 feet.

Stratigraphy.—The mountains consist of a series of sedimentary rocks, ranging from lower Cambrian to post-Tertiary. These are, for the most part, conformable. Lenticular layers of trap from a few inches to six feet thick have been observed in a few localities. This is the only igneous rock in the region.

Saline Series.—Occurring usually at the base of the formations is a series of beds of red marl, gypsum and rock salt. The series outcrops along the southern face of the mountains for a distance of 134 miles. It is probably four miles wide for most of the way, and may be twelve in places, its thickness varying from 800 to 1,500 feet.

The salt occurs in solid beds, which generally underlie the thickest development of gypsum. They alternate with brownish beds of *kallar* or impure salt. The beds are from 6 to 30 feet, and, in some cases, as much as 100 feet thick. At the Mayo mines, towards the eastern part of the range, where the thickness of the saline series is 1,000 feet, the rock salt is 275 feet thick, and the kallar another 275 feet. As far as can be made out, the beds are not continuous, one layer thinning out and being replaced by another. The layers of salt have been tilted and bent from the disturbance which they have suffered in common with the overlying deposits. The dip at Wurcha, in the southwestern part of

[171] Memoirs Geological Survey India, vol. xiv, 1878, plates, maps and sections.

part of the range is 20° to the northwest and 70° to the west at Kalabagh, on the western end, just across the river Indus.

The red marl, associated with the gypsum and salt, is without stratification and contains no organic remains.

The gypsum appears to be formed by re-crystallization from anhydrite, with which it has been shown to be intimately mixed in specimens from several localities.

Age and Origin of the Series.—Different geologists have held radically different views on the origin and age of the red marl and its associated beds. H. B. Wynne [172] in a memoir on the Salt Range, written in 1878, classed them as sedimentary deposits of lower or pre-Cambrian age.

C. S. Middlemiss [173], in a paper published in 1891, advanced the theory that the series had been formed by the intrusion of a magmatic scum from below, accompanied by induced changes in limestones or dolomites above. The theory was based on the occurrence of the marl along the cores of folds and flexures, into which it appeared to be intruded, and also on the condition of dolomite pebbles found in the marl, which had apparently been corroded by their matrix, and showed all gradations from fresh dolomite inside to true marl. He thought the formation was of Tertiary age.

. D. Oldham, [174] in 1893, on the basis of later investigation on the origin of the gypsum particularly, favored the idea that the series had been formed by the metamorphosis of pre-existing sediments of unknown composition by ascending acid vapors or solutions.

Methods of Working.—At Kalabagh, where the beds outcrop on the side of the ravine, they are worked by a number of open quarries..

At Kheura, Sardi and Wurcha, the salt is worked by drifts and tunnels in the side of the mountain. Salt has been mined here since the reign of Akbar (1500). Formerly many more

[172] Memoirs, Geological Survey of India, vol. xiv, 1878, plates, maps and sections.

[173] Records Geological Survey of India, vol. xxiv, 1891, plates and sections.

[174] "The Geology of India," by R. D. Oldham, 1893, p. 111.

mines were operated and large caverns were excavated in a unsystematic way in the mountain side. The work was done e tirely by hand and the mines were ill-planned and dangerou Since 1870 all the mines but two or three have been shut dow those now in operation being worked by modern engineerir methods.

The Mayo Mines.—These mines, which are situated in the Sa Range, at Heura, are among the most important of the salt min of India. Daily 1,100 persons—fathers, wives, children—wi their flickering lamps of vegetable oil and their hammers, pa into the thick darkness of the galleries and chambers, which e tend for miles into the hill.

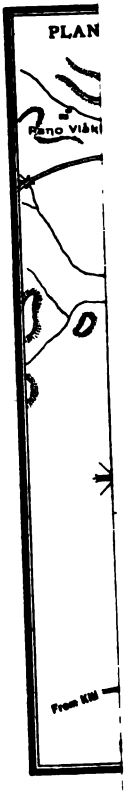
The salt is pink in color. Several immense chambers have be cleared as large as cathedrals, and in these, on show occasio balloons are sent slowly rising to the far-off ceiling, lighting the colored walls as they go. Bengal lights add to the wei effect.

Extent and Production.—A conservative estimate places t amount of salt in the range at ten cubic miles. The supply therefore, practically inexhaustible. The average production tween 1860 and 1871 is given as 1,291,148 maunds per ann (one maund equals 80 pounds), valued at 3-1 rupees, or $1.37 maund. Twenty-two million cubic feet of salt are estimated have been removed by mining up to the year 1870; 1,500,(tons were produced in the Mayo mines from 1870 to 1889. T represents 80 per cent of the total production of the range.

Chemical Analysis.—A table is given below, showing the a age composition of four samples of commercial salt taken fr the Mayo mines:

Earthy Matter.	Per Cent Trace.
Calcium sulphate	.75
Calcium chloride	.50
Magnesium chloride	1.25
Sodium chloride	93.00
Water and loss	4.50
Total	100.00

LA. GEOL.



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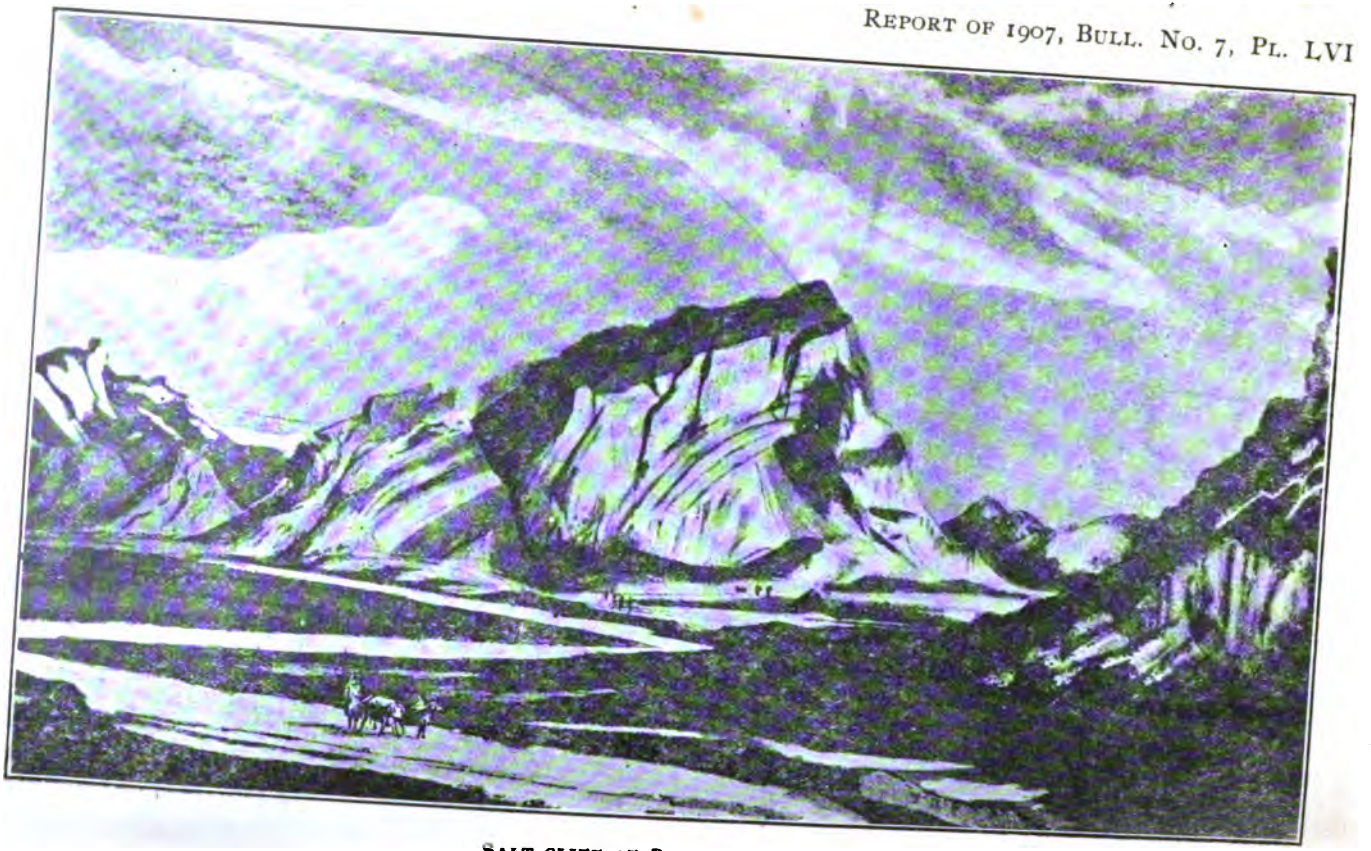

SALT CLIFF AT BAHADUR KHEL
In the Trans-Indus region, India

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175 Memoirs Geological Survey of India, vol. xi, pt. 2, 1875, map, sections and plates.

THE TRANS-INDUS OR KOHAT SALT REGION.[175]

Location.—The Trans-Indus region, containing about 1,000 square miles of country, lies a little to the northwest of Kalabagh. (See Plate LV.) It extends from Kohat southwest to Banner, and from the Kuram river, on the west, to the Indus.

Geological Features.—The district is traversed by a system of parallel east and west anticlinal ranges, made up of a series of Tertiary limestones, sandstones and clays. The limestones are the defining beds of the anticlines and are underlain from above downwards by red clay (20-300 feet), gypsum (20-200 feet), and rock salt.

Occurrence of the Rock Salt.—The salt occurs in patches exposed as naked cliffs on the valley sides. Because of the solubility of the whole series below the defining limestones, the extent or presence of the salt between two exposures is entirely a matter of conjecture. In any given exposure it is always the lowest rock in the series. Its depth below the surface or the character of the underlying rock is not know. Planes of stratification are well developed and are sometimes marked by thin clay laminae. Earthy impurities are, however, rare, and the salt occurs in one solid zone which is, in one instance, over 1,000 feet thick.

The outcrop of solid in the valley of Bahadur Khel (See Plate LVI) ranks with that of the Namak Mountain in Persia as the most remarkable surface exposure of salt in the world.

Composition.—Excepting the earthy laminae mentioned, the salt is remarkably pure. The upper few feet are often bituminous, smelling strongly of petroleum. The mass of the salt contains approximately 2% calcium sulphate, with practically none of the alkali or magnesium chlorides or sulphates. It differs markedly in this respect from that mined in the Salt Range, where there are more of the lighter salts and less calcium sulphate.

Methods of Working.—Almost all the salt is worked by open quarries and has been for the past twelve centuries. In a few instances tunnels have been driven into the hillsides for about

[175] Memoirs Geological Survey of India, vol. xi, pt. 2, 1875, map, sections and plates.

50 feet. Blasting by powder is done in some quarries, while others are worked entirely by hand.

Extent and Production.—There are altogether 335 outcrops with a surface area of something over 3,000,000 square feet. The salt at Bahadur Khel alone should at a very reasonable estimate, yield 40,000,000,000 mauds or about 11,700,000,000 barrels of 280 pounds each. Evidently then the supply from this region can also be considered inexhaustible.

The waste per annum, dissolved and carried off by rain water, is estimated at something over 200,000 barrels, with an average rainfall through the region of 14.19 inches.

The yearly average output from 1898 to 1903 was 16,133 metric tons and 15,836 tons were produced in 1904.

THE MANDI MINES.

The Mandi mines are situated in the Himalayas in the State of Mandi, northwest of the hill station, Simla, and near the source of the Beas River.

The salt beds occur on the western slopes of a range of north and south mountains which stretch from near the city of Mandi northward to the 32 parallel. The two mines now worked are at Guma and Drang. They are controlled by natives and the salt is simply quarried out. The average yearly production from 1898 to 1903 was 4,770 tons and 4,623 tons were produced in the year 1903-1904.

MINOR LOCALITIES.

According to an old report, rock salt occurs at Scardo in the Baltistan district of Kashmir.

Some rock salt is produced in the Himalaya State of Bhutan and exported to Assam. Rock salt is mentioned as the chief product of Jumla in Nepal, but no further descriptions have been given.

SALT LAKES AND BRINE SPRINGS.

Salt is made from the brine in salt lakes or springs in the Rajputana Agency, Bombay Presidency, in Burma and to a lesser extent in the Pujab and Kashmir.

Assam possesses rich brine springs in the Vaga Hills but they are no longer worked.

Kashmir.—There are some salt lakes in the valley of the Indus River in Kashmir. A small quantity (6 to 24 tons per annum) of poor salt is made from them for local consumtion.

Pujab.—Salt is made from brine springs in an area 15 miles square at Sultanpur, southwest of Delhi. The salt is of poor quality and slightly bitter taste and hence the output is diminishing. The annual average from 1898 to 1903 was 2,603 tons and 2,836 tons were produced in 1903-1904.

The Rajutana Agency.—There are numerous salt lakes in this province. The more important salt producers are Lakes Sambhar, Didwana, and Fallodi.

Sambhar Lake.[176]—This lake lies between Jaipur and Ajmir and is three feet deep at its deepest point. A series of determinations of the specific gravity of its brine showed a variation of from 1.03 at the end of July to 1.20 in February. 1.03 is approximately the specific gravity of sea water, while 1.2046 is the specific gravity of a saturated solution of salt.

Two sample of brine taken in December and January on analysis were found to yield 21.9% and 27.8% of dry residue respectively, of which 19.9% and 24.8% was sodium chloride, the rest consisting of sodium sulphate and carbonate in the proportion of four and five to one.

Didwana and Fallodi Lakes.—At Didwana, 38 miles northwest of Sambhar, salt is made from the brine obtained from shallow wells in a dry lake bed. The average annual production from this lake bed is 8,131 metric tons and from Lake Fallodi about 200 tons were produced in 1896.

Bombay.—In the province of Sind salt is made from the salt lakes of Sarun and Dilyar and is used by the inhabitants of these districts.

Burma.—Salt has been made from brine springs in Upper Burma since very early times. Formerly it was used in the same way as it is still used as currency in Central Africa.

It is twenty miles long by five miles wide, and after the rainy

[176] Records of the Geol. Survey of India, vol. 13, pt. 3, 1880.

EARTH WORKS.

The term "earth works" has been employed by writers on Indian geology for the process of salt manufacture from saline soils. This method of obtaining salt was formerly very common in certain parts of India and Beluchistan, but the cheapening of the cost of transportation in the interior has brought Indian sea salt and foreign salt into the market and the industry has almost died out; but is still made from saliferous soils in Beluchistan, Burma and to some extent in Madras.

In Beluchistan salt is made in earth works at Kaubirar, in the southeastern State of Luz; near Hamun Mashkel, in the northwestern State of Karan; at Gajin, Ihall and Shoran, in the State of Kelat and in the Agency Territories in the Zhob and Chagai districts. In Burma the brine obtained from the earth works is boiled in earthen pots or iron cauldrons. And in Madras salt is gathered or made from natural residues in Panchakali, in the Tinevelli district on the Gulf of Manar; at Vedaraunijam, in the Tanjur district and at Pondraka in the Kistna district.

SALTPETER REFINERIES.

Salt is made as a product of saltpeter refineries in northern India and Bengal. The factories of northern India produced 1,873 tons a year between 1898 and 1903. Those of Bengal are in the ditsrict of Orissa and Behar especially in Calcutta and its suburbs; but the output is very small, amounting in 1904 to only 96 tons.

CEYLON.

Salt is made on the Island of Ceylon[177] from sea water in the shallow lagoons of its northern and western coasts. There are no rock salt deposits or brine springs.

The most important salines are at Puttalam, in the northwest province, and Hambantota, in the southwest province. The yearly production is about 20,000 tons, about half of which is refined.

The salt works are the property of the government.

[177] Von Buschman, Das Salz, vol. 2, pp. 36-71.

AFGHANISTAN.

There are very few records of the salt industry or the occurrence of rock salt in Afghanistan. Different travelers declare that there is plenty of salt in the country and the Emir has prohibited the importation of salt to encourage its exploitation in its own domains.

The Hindukush Mountains probably carry salt at their western extremity like the mountains in the neighboring territories of Persia and Turkestan. In the same way the Sefid Kuh range, of which the Trans Indus salt region in India is a prolongation, probably has salt deposits in its Afghanistan end.

Many salt steppes occur in the southwest. One of them through which the Helmand River flows is known as the Desht Registan on the eastern and the Desht-i-Margo on the western side of the river. The word *desht* means a salt desert.

A bitter salt lake lies in a desert void of vegetation on the Ghilzai plateau. It is 12 feet deep and 44 miles in circumference. The valley of the Amu Daria (Oxus) in Afghanish Turkestan is looked on as a salt producing region.

Although some salt is smuggled into the country a considerable amount must be made to supply the 4,000,000 inhabitants, but no statistics of production exist.

PERSIA.

Persia[178] is especially rich in deposits of rock salt which crop out in all parts of the country. (See Plate LIV.) Besides rock salt deposits there are many salt rivers, lakes and plateaus. The salt made comes principally from rock salt deposits; the waters of the Persian Gulf and salt lakes.

SALT RIVERS AND LAKES.

The surface of the interior consists of a series of plateaus broken up or separated by mountain ranges. These mountains frequently carry rock salt formations and in consequence the streams coming from them are salty and in dry seasons deposit salt crusts in their own beds or in the beds of shallow lakes or swamps in the plateaus. When the plateaus are inland basins

[178] Von Buschman, Das Salz, vol. 2, pp. 169-179.

and the lakes have no outlet this process is of course more noticeable. Practically all the larger rivers and lakes in Persia are salty to some extent, and some of the plateaus are covered with a salt efflorescence or rust.

The composition and amount of salts in the rivers and lakes varies considerably in different localities.

The most productive of the many salt lakes in which deposits of salt are formed are lakes Urumiah, Niriz and Mamlu, southeast of Shiraz.

Lake Urumiah.[179, 180]—This lake is the largest inland body of water in Persia. It is near the city of Tabriz. The length of the lake is 82 miles, its greatest width is 24 miles and it lies 4,100 feet above the sea. The average depth of the lake is about 10 feet, but in some places it is as much as 25 feet deep. It is said to be diminishing in area and in confirmation of this a great part of its shore is now in the condition of a salt marsh. The water is very saline, containing up to 20% of salt. The natives make a bitter salt in lagoons along the shores, which is used only locally and sells for about half the price of rock salt. But it is on record that in 1854 large quantities of this salt were exported to the Turkish domain.

SALT PLATEAUS.

The salt plateaus, or steppes, of Persia are known as *Kavires.* Some of these lie in the highest parts of the plateau regions. The most remarkable of all is the Sand or Salt Desert in central and eastern Persia. This great *Kavire* extends from Teharan south to Ispahan and thence in an easterly direction to the borders of Afghanistan and covers approximately 64,000 square miles. It consists of a trough-like depression surrounded on all sides by mountains. Vegitation is scarce and salt swamps abundant.

Kavires are also found between Lake Niriz and Saidabad in central Persia; and a number of similar salt steppes occur elsewhere on some of which borax is found.

179 W. K. Loftus, Geol. Journ., vol. 2, 1854, pp. 306-309, with sections.

180 R. Helmhacker, Eng. and Min. Journ., vol. 66, 1898, p. 38.

ROCK SALT.

Rock salt of Miocene age is very widely distributed in Persia. The whole southern slope of the great Elburz Mountain system on the northern border of Persia carries salt and gypsum and the saliferous formation extends eastward into the mountains of Afghanistan. The broad belt of mountains along the western part of Persia also contains rock salt in a great many places, especially along the shores of the Persian Gulf. Some very large deposits are found on the islands in the Straits of Ormuz.

The rock salt is mined chiefly in three regions; in the northwest, in the province of Azebijan and from there southeast along the Elburz Mountains; in the northeast, in a number of east and west ridges northwest of Nishapur not far from the Russian boundary and in the southeast along the shores of the Persian Gulf.

THE NORTHWEST REGION.[181, 182]

Location.—There are indications of a large salt deposit near the Aras River, on the Russian border. Large masses of salt occur at Hadjichai, near the foot of the Savellan Mountains; in a small hill near the plain of Khoi about 16 miles north of Dillman; at Sahend, south of Tabriz; west of Sofian and at Duzkend. The salt-bearing formation stretches from the last mentioned locality northward through Mianeh and is mined at Maman, one day's journey north of Mianeh. Further south salt occurs in both slopes of the Kurdistan Mountains, one outcrop being near Lake Urumiah. Salt is also mined at Deh Nemek and at a number of other localities in the southern slopes of the Elburz Mountains. South of Teheran a large deposit occurs west of Kum.

Occurrence.—In the salt hill of the Plain of Khoi light gray and blue marls are overlain by coarse-grained sandstones which are capped by red marls and red standstones containing salt crystalls. The salt occurs as crystalline masses in the blue marl.

At Maman the salt lies in small mountain ranges and is accompanied by thick beds of gypsum with which yellow marls and

181 Loftus, Geol. Journ., vol. 11, 1854, pp. 306-309, with section.

182 E. Tietze, Jahrb. der K. K. Geol. Reichsanstalt, vol. 29, 1879, p. 566.

variegated clays occur. These lie in troughs of the Supra Nummulitic limestone which rests on the southwest slope of a chocolate and violet gray porphyritic trachyte, forming a ridge of the Kafilan Kuh range. The potassium salt, carnallite, occurs as red nodules in the highest bed of salt. The mineral mamanite, a complex potassium and magnesium salt, sometimes forms a filling between the carnallite nodules or a thin rind over them. The manner of occurrence of the potassium salts is more like the Stassfurt deposit in Germany than like the Kalusz deposit in Austria.

At Duzkend the dark limestone is overlain by red conglomerate, reddish gray marl and an extensive gypsum deposit in which a very pure white salt occurs in large quantity.

THE NORTHEAST REGION.[183, 184]

Location.—Salt is mined in three places in the province of Khorassan: Near Sherifabad, 24 miles south of Meshed; at the Abju mine, 15 miles from Nishapur and at the Turquoise mines, 32 miles northwest of Nishapur.

Occurrence.—The salt occurs in beds interstratified with thin layers of clay. Its aggregate thickness is given as from 400 to 500 feet. Gypsum occurs in connection with the salt and they underlie red marls and conglomerates. There is an occurrence of white salt in one of the mines, but most of it is gray and even black. Schindler, writing in 1881, gives the output from the mines in this region as 750 metric tons a year. A record dated 1834 tells of the government leasing out the mines for 300 toman ($571) per year.

Variegated sandstones and red marls enclosing gypsum appear all along the northern edge of the Shah Rud desert as far as Herat in Afghanistan.

183 Schindler, Jahrbuch der K. K. Geologischen Reichsanstalt, vol. 31, 1881, p. 176.

184 "Turquoise Mines of Nishapur, Khorassan," by A. Hontum Schindler, Rec. Geol. Survey India, vol. 17, p. 140.

PERSIAN GULF REGION.[185, 186]

Distribution.—Salt-bearing marls and clays occur in the ranges near the Persian Gulf from Bushire to Bender Abbas at the Straits of Odmuz, and on the islands in the straits.

Salt deposits are also found inland on the south side of the Kahur Pass between Bender Abbas and Kirman, where there are two beds of salt and on the road between Shiraz and Bushire. Salt is also found at Namak Mountain, on the left side of the River Mand, 74 miles up from its mouth.

Namak Mountain.—The hills of the Mand River consist of saliferous clays which are partly protected from the weather by beds of sandstone. They are of various colors and have been carved into many fantastic shapes by erosion. The clay carries from 25% to 30 %of salt. The salt mountain is an eastern spur of one of the ranges parallel to the coast. Its core is made up of chalky marls and solid limestone alternating with thin beds of gypsum. Its summit is 5,250 feet above the sea level. The whole mountain appears to be covered with a layer of salt which is 10 to 13 feet near the bottom and increases in thickness farther up, so that at 2,000 feet above the valley it is nearly 100 feet. The upper third of the mountain appears as a solid block of salt which forms perpendicular, unscalable cliffs. The color of the salt is reddish brown or black. It has been deeply sculptured by the rain wash. The mountain is estimated to contain 48,000,000 to 50,000,000 metric tons of salt.

The Island of the Straits.—On the Island of Ormuz dolerites and trachytes are associated with the salt beds with which there are a few layers of inter-stratified shales and sandstones. One writer also mentions gypsum as occurring with the salt. The salt beds are much disturbed, dipping to the northeast in one place, while on the opposite side of the island the dip is in the opposite direction. The salt formation forms hills 300 to 400 feet high.

[185] "Salzvorkommen in Sud-Persian," Zeitschrift fur Prakt. Geologie, vol. 1, 1893, p. 43. Review of an article by Hans Winkelmann in Osterreiche Zeitschrift fur Berg und Huttenw., vol. 40, 1892, p. 579.

[186] "The Salt Caves and Mines in the Persian Gulf," Journal of the Society of Arts, vol. 29, 1880-81, p. 735.

On Larak Island the salt beds are underlain by calcareous clayey sandstones of the Tertiary with *Ostrea* and *Pecten*, and overlain by calcareous sandstone. The salt is accompanied by gypsum and is mixed with marl and clay so that it is of poor quality. Some of the beds are 60 feet thick.

A remarkable natural gallery in the salt, 5,000 feet long with chambers 38 feet high, has been described by one writer.

The salt on Henjam Island is very similar to that on Larak. Large crater-like hollows occur on the surface of the salt formation, which are caused by the salt beneath dissolving away.

On Kisham Island there is a hill 3¾ miles long and about 1,300 yards wide and 300 to 500 feet high, which is nearly all solid salt. One writer states that the salt is overlain by red ochre and specular iron ore. According to Von Buschman, the surface is overlain by 35 to 60 feet of sandstone, marl and gypsum on the western end of the hill. The salt dips to the east and the upper formation becomes thicker in that direction. The salt, though colored on the outside, is white when pulverized. It contains pure sulphur and iron pyrite. Many caves have been formed in the salt by underground solution. One of these was used as a mine and so much salt was taken out that the opening became 90 feet high and 1,650 feet in circumference. It then caved in and killed many of the workmen.

Methods of Working.—At one point where the salt formation is close to the shore the Arabs have made shallow openings in the cliff, working with primitive iron tools and using explosive powder of their own make. After the salt mass is jarred loose it is broken up into small pieces and tumbled down the side of the cliff, from the bottom of which it is carried by workmen in baskets to the beach. About 2,000 workmen are employed and because of the scarcity of water no work is done between October and May. The men are paid 10 shahi (about 10 cents) a day and have to furnish the explosive powder themselves.

Hameran.—The deposit at Hameran on the Persian Gulf, is in beds 4 feet thick alternating with earthy material. The salt is carried by native boats to Muscat, whence it is shipped to Zanzibar, Mauritius, Bengal and other ports.

In the early "eighties" the region around the Straits of Ormuz produced from 25,000 to 30,000 tons of salt.

SEA SALT.

Salt is made from the water of the Persian Gulf at Bushire. Sea and lake salt are not taxed, but rock salt is.

PRODUCTION.

There are no records of the total amount of salt produced in Persia, but a rough estimate would place it at from 60,000 to 70,000 metric tons a year.

TURKISH EMPIRE.

GENERAL OCCURRENCE.

The great salt wealth of Turkey is in Asia Minor;[187, 188] but one rock salt deposit has been found in Albania in the western part of European Turkey.

Until recently European Turkey was supplied almost wholly with foreign salt, but now Turkish evaporated salt is used and no salt is imported.

In Asia Minor 75% of the salt produced is made from sea water, 22% from salt lakes and brine springs and the remaining 3% from rock salt.

SEA SALT.

Most of the salt made from sea water comes from the western coast. The Black Sea is too fresh for salt making and the rocky character of the southern coast is unfavorable for salterns.

On the western coast (see Plate LIV) there are salines near Panderma on the Sea of Marmara; on the Islands of Lemnos and Mytilene; at Assos on the Gulf of Adramyti; at Aivaly; on the Gulf of Mendelia south of the Island of Samos, and on the Gulf of Tchandarly. On the southern coast there is a saline at Adana on the Bay of Alexandretta.

SALT LAKES.

The valley of the Kizil Irmak River is rich in salt deposits and salt lakes. Salt is made from Lake Tuzcholli, due east from Kaisareh (Ceasarea); from Pallas Lake, 31 miles northeast of Kaisareh; Lake Sarimsak, 7 miles north of Kaisareh and from a lake near Kiangri.

187 Von Ruschman, Das Salz, vol. 2, pp. 147-167.
188 Eng. and Min. Jour., Nov. 26, 1898, p. 636.

Lake Tuzcholli is the most important of these lakes. It is 45 miles long and 18 miles wide and is very shallow. In the summer it partly dries up and leaves a crust of salt from two inches to six feet thick. The Turkish government harvests the salt at various localities which are known as *Khans*, and keeps a strict guard over the lake while the salt is being gathered.

ROCK SALT.

Of the rock salt deposits in the Kizil Ormak valley the following are the most important.

West of Lake Tuzcholli and northeast of Konieh is a salt desert which is covered with a white saline efflorenscence, and in the hills east of the lake there are red, salt-bearing sandstones with alternate beds of gypsum. Salt-bearing sandstones are also found near the source of the Kizil Irmak in the neighborhood of Tosgani, and salt occurs with gabbro and dolomite near Siva. There are salt mines at Tuz Hissar, a town near lake Tuzcholli; at Hadji Bektash on the right bank of the Kizil Irmak near where it turns northward; and on the left bank at Tuzkioy, near Nevshehir, south of Tadji Bektash. In the Tuzkioy mines the salt is in beds 40 feet thick and about 2,000 tons are annually produced. An extensive salt deposit lies east of Angora and extends from Kiangri on the left bank of the Kizil Ormak to Tchorum on the right bank, and from there south to Yuzgad. This deposit is exploited at Magahara near Kiangri; at Sekilo near the Delidje River; at Tchankioj, northwest of Yuzgad, and at Tepisidelik, near Kirshehir.

According to Hamilton,* some of these rock salt deposits occur in horizontal beds in basins formed by almost vertically dipping red sandstones with a general north and south strike. The salt is with clay, gravel and sand. The red sandstones occur above Nummulitic limestones which are of Lower Eocene age.

PRODUCTION.

The yearly average production for Asia Minor between 1898 and 1903 was 173,438 metric tons.

*Geological Journal, vol. 5, 1849, p. 373, with sections.

TURKISH ARMENIA AND KURDISTAN.[189]

Several rock salt deposits occur in Armenia and Kurdistan, usually in remote mountain regions. And in Armenia the official reports give 26 localities where salt is made from brine. Among these are the springs of Parinek and Dulassi; those at Bayazid, southwest of Mount Ararat, and the salt stream Arnat, near Mush.

Rock salt is found in the district of Tuzla; at Saghir Caya, in the province of Erzerum and north of Erzerum in the rugged mountain valleys of the Olti and Tortum Su Rivers, which are tributaries of the Chorok. In this region the salt occurs in a white, gray and red salty clay, in which occasional fossils are found. A good deal of salt is also found in the watershed area of the Chorok and Euphrates, where it occurs with gypsum and clay.

The Turkish official records mention seven localities in Kudristan where salt is made from brine springs.

PRODUCTION.

From 188 to 1903 Armenia and Kurdistan together produced an average of 18,289 tons of salt yearly. Of this Armenia produced 11,156 tons of rock salt and brine salt and Kurdistan 7,133 tons of brine salt. Only 200 tons in all were rock salt; all the rest was from brines.

MESOPOTAMIA AND EL HASA.

ROCK SALT.

Rock salt has been found in the Hamerin Mountains in Mesopotamia, but apparently it is not exploited. At Dillo Mountain between Kifri and Salamanieh salt occurs with gypsum and crude oil, and Ainsworth found a bed of salt near the Tigris River in the district of Mosul. Northeast of Kifri at Tuz Khurmati there is a rich salt deposit.

BRINE SPRINGS.

There are about 80 salines in Mesopotamia, of which a half dozen are controlled by the government and the rest are worked

[189] For a fuller description of Armenia see Mem. Acad. St. Petersburg, 6th series, vol. 9.

unsystematically by the Bedouins, Arabs and Kurds. Some of the brine springs are associated with springs of petroleum and bitumen. Salt swamps and lakes occur along the Euphrates south of Hit.

The most important salt producing localities are chiefly in the southern part of Mesopotamia. Among these are Bevaria, southwest of Mosul; Ashkar, southwest of Mosul; Samarra; Silsar, near Samarra; Shifattije, northeast of Kerbala; Shadi, southeast of Kutel-Amara. and Hammar.

The estimated production of Mesopotamia is 16,000 tons a year.

SYRIA.

Syria has several salt lakes, chief of which is the Dead Sea, a remarkable and historic body of water in Lower Palestine. Several important deposits of rock salt also occur and one locality is mentioned where salt is made from brine springs.

ROCK SALT.

Salt is made at the Lake of Sabakha, about 18 miles east of Aleppo, where over 10,000 tons are produced every year and the output could easily be increased to 70,000 to 80,000 tons. Salt is also won from a lake at Tadmor.

THE DEAD SEA BASIN.[190, 191]

The Dead Sea is about forty miles long in a north and south direction and about eight miles broad at its widest part.

Lieut. W. F. Lynch, of the United States Navy, by a line of levels run in 1848, found the surface of the sea to be 1,316.7 feet below that of the Mediterranean. Its greatest depth, according to his soundings, was 1,308 feet. According to Lartel, this basin is situated along a north and south dislocation of Pre-Cretaceous age, the depression having been formed by a Post-Eocene sinking of the land on the eastern side of the fracture.

190 For more complete description see Lartel, Bull. Soc. Geol. France, vol. 22, 1864-1865, pp. 420-462, with section and map, and vol 23, 1865-1866, analyses, section and sketch.

191 Lynch, Dead Sea Expedition, 1848.

The water of the sea is very heavily charged with salts, some determinations giving a total of 24% of salts of various kinds.

Chemical analyses of the contained salts are given below:

	ACCORDING TO	
	Fürer.	Ramsay.
Sodium chloride	6.2438	12.110
Potassium chloride	1.4250	1.217
Magnesium chloride	10.8015	7.882
Calcium chloride	2.9811	2.445
Calcium sulphate	.1021	.....
Sodium bromide	.4236	.....
All other salts	.....	.452
Total	21.9771	24.106

This strongly saturated water is totally void of organic life, except for some small fishes at the mouth of the Jordan and this fact with the almost entire absence of plant life on its shores has given it the name of the Dead Sea.

ROCK SALT.

The Quarternary flanks of the basin are frequently saliferous and there is an important deposit of rock salt at Djebel Usdom on the southern shore. Salt is also to be obtained from the valley of Eugeddi, in the central part of the western shore of the Dead Sea.

Northeast of Damascus there is a deposit of rock salt at Djirud. The salt is obtained from a crust which is formed by the evaporation of natural brine which is derived from the rock salt. But the product is bitter and is only used locally.

Djebel Usdum.—The salt mountain of Djebel Usdum is an isolated hill at the southwestern corner of the Dead Sea. It runs in a general north and south direction with a western deflection at its southern end and is about four miles long by less than a mile wide. The base of the hill on the west side is composed of from 50 to 60 feet of rock salt. This is overlaid with red and green clay with gypsum crystals. Over the clay is a white chalky limestone, which forms the crest of the hill. The top of the limestone is about 300 feet above the plain. According to Lartet, this limestone and the salt below are of Upper Cre-

taceous age. Max Blackenhorn,[192] however, places them in the Quaternary.

The exposed salt is of a bluish color and has been carved into columns and pillars of peculiar shape by the weather. It contains a high percentage of sodium chloride. An analysis by M. Levreil gives the following composition:

Chlorine	59.30
Sodium	38.47
Sulphuric acid	.92
Calcium	.60
Magnesium	.09
Silica, clay and organic matter	.15
Sulphur	Trace

The Arabs work this salt[193] and deliver it in Jerusalem for 60 piastres ($2.56) per camel load (500 pounds). The purchaser pays 15 piastres extra per load as a revenue tax to the government.

Zuweirah-Foka.—In this locality, about 13½ miles northwest of Djebel Usdom, there is a minor occurrence of rock salt in connection with a large gypsum deposit. The formation is of the same age as that at Djebel Usdom.

BRINE SPRINGS.

From 2,000 to 3,000 tons of salt are produced annually at the Saline of Jezreb, near the villages of Kiaf and Etreb, in an oasis of the Syrian desert. The salt is sent to Damascus and Hauran.

PRODUCTION.

The average yearly production of the salt works owned by the Turkish government in Syria and Palestine from 1898 to 1903 was 8,059 tons.

TURKISH ARABIA.

Several large deposits of rock salt occur in the mountains along the west coast of Arabia, and salt is also made from sea water along the coast.

ROCK SALT.

A red salt is mined in the mountains near Yambo ,north of Mecca and sold in the bazaar. And it is said that large masses

192 Zeitschrift fur Praktische Geologie, vol. 5, p. 360.

193 "Notes on a Visit to the Dead Sea," H. Poole, Geol. Jour., vol. 12, p. 203.

of rock salt lie in the mountain slopes near Jisan, Loheia and Hodeida. The largest mine is in the mountains near Salif, where 50,000 tons of rock salt are produced in addition to the sea salt.

Salt steppes lie in the lava waste of Harra, north of Mecca and between the coast ranges and the interior desert.

SEA SALT.

Salt is made in several salines along the coast and on quite a large scale at Salif, where the salterns are owned by an Englishman. And at Aden, which is an English possession, there is a very large plant with about 4,000 square yards of evaporating basins. The water is let in from the ocean by sluices and is run from one basin to another as the process of evaporation proceeds, so that a fairly pure product is obtained when the salt finally crystallizes. The mother liquor is pumped from the basins back into the ocean by screw pumps worked by hand. This locality, on account of the tremendous heat, a maximum temperature of 117° Fahrenheit, and the warm winds which prevail at one season of the year is especially adapted for salt making. The brine evaporates in six or seven days, the salt is then broken up and left in heaps to dry. Most of the dried product is ground up in a mill, transported to the loading points in small trams drawn by camels and dumped into the holds of the vessels without packing.

The average yearly output for this locality between 1893 and 1902 was 50,120 metric tons.

PRODUCTION.

In Turkish Asia an average production of 249,488 metric tons a year is given by the official figures for 1898 to 1903 Of the total product, 52,814 tons was rock salt, 67,039 tons brine or lake salt and 129,635 tons sea salt.

The production in 1903 was 280,178 tons, of which Asia Minor produced 193,307 tons; Armenia and Kurdistan, 20,924; Mesopotamia, 1,035; Syria, 7,874, and Turkish Arabia, 57,038. It should also be borne in mind that in addition to this estimate a great deal of salt is made in the desert by the wild tribes.

ARABIA.

A good deal of sea salt is produced in Arabia. All the lowest parts of the Arabian desert contain salt flats and many of the

crusts in them are gathered and used by the Nomadic tribes of the interior. There are two occurrences of rock salt.

ROCK SALT.

A salt bed occurs at the Oasis of Teyma, latitude 27° to 28° North and longitude 39° to 40° East. It is worked by the wandering Bedouins and used extensively in the Arabian desert. In southern Arabia, in the region of Hadramaut, some salt comes from Schebwa, Abida and Iyad, which are about six days' journey from Schibam.

SALT FLATS.

Salt crusts or beds are worked in the two salt flats of Aneisa at Kheybar, 26° North Latitude, 40° East Longitude and at Mount Misma, from which locality the town of Hail is supplied. A salt desert occurs in the volcanic region of Harrat el Kishub, Latitude 23° to 24° North, Lontigtude, 41° to 42° East.

SEA SALT.

Sea salt is made at Makalle and Sihut on the southern coast. The salt is obtained from *agas,* or low salt flats. They are filled with ocean water when the southwest monsoon drives the waves in and at other times receive the waters from the streams coming from the inland hills. The Arabs dig shallow holes in the salt flats and the brine which collects in them is evaporated.

A large part of the product is exported to East Africa. At Sihut 50 sacks of about 65 pounds each sell for $64 and probably bring that price apiece in East Africa.

Arabia produces enough salt for home use, but there are no statistics of production.

EGYPTIAN ARABIA (The Sinai Peninsula).

Rock salt outcrops are found at Gharendel, Wady-Tal and Wady-Roman. Old salt quarries occur at Omshash, on the northern edge of the Et Tih desert. Sea salt is made in shallow flats along the Gulf of Akabah, on the east coast of the peninsula. At Cape Mohammed and Ras om Haye, where the coast is rocky and the waves very high, the spray from the waves fills cavities in the rocks, which leave a salt crust on evaporation. The common salt in these crusts is easily separated from its other impurities and is used to some extent for preserving fish.

There are many bitter salt lakes along the Suez Canal, which are not used. South of Port Said an Italian company has obtained a concession from the Egyptian government to make salt for export. They have laid out a saline capable of turning out 150,000 metric tons of salt a year.

THE ISLAND OF CYPRUS.

VICINITY OF LARNACA.

The Salt Lake.—Large quantities of excellent salt are obtained from the salt lake, which is about a mile to the southwest of the town of Larnaca,[194] on the southeastern side of the Island of Cyprus. (See Plate LVII.) This lake is of especial interest, as it illustrates the formation of salt deposits.

The lake and the sea are separated by a barrier which is nearly level and a mile to a mile and a half wide. This belt is covered with low brushwood and patches of bare ground. During the winter the bare spots are covered to a depth of a few inches with water, fresh, brackish, or salt. Southward they form backwaters of considerable area.

The surface of the lake in winter is seven feet below the surface of the sea. The lake at its deepest is only about three feet.

Section of the Barrier.—Under the direction of Mr. Bellamy, a boring was made into the barrier, and the following section was obtained:

On the surface was a layer of yellow, calcareous, or shelly sand 12 to 18 inches thick; then came a thin layer of black mud corresponding to the deposit in the bed of the lake. Between the depths of two and ten feet, shelly sand again appeared. In the upper layers this was stiff, but between 10 and 12 feet below

194 The following description is chiefly from Bellamy, "Salt Lake of Larnaca," Geol. Soc. London, vol. 56, 1900, pp. 745-758.

the surface it became very soft and watery. Beneath this horizon of water mud 12 to 15 feet of stiff clay were penetrated, but the boring had then to be discontinued, as the material became so hard as to clog the boring rods. Ten days after it was found that the underground salt water had welled up the bore hole and formed a pool. This water had more than twice the normal density of the sea water and about .75% that of the water of lake at the time of observation.

Inflow of Sea Water.—Because of the lower level of the lake, the sea water constantly percolates through the shelly layer (a), and in the winter seasons accumulates as a salt lake. This inflow is, however, not sufficient to raise the surface of the lake up to that of the sea, because of the occurrence of impervious masses of conglomerate in the shelly layer.

The rate of evaporation during the intense heat of the Cyprus summer prevents the accumulation of any water, but when winter sets in, evaporation diminishes, and with the aid of a few showers of rain, the supply of sea water overcomes the loss by evaporation. Then water appears in the bed of the lake, which in summer had been covered only with salt incrustations.

Diversion of the Rivers.—To obtain the greatest possible amount of salt, the two principal mountain streams have been diverted by artificial channels from entering the lake.

HISTORY OF THE SALT LAKE.

In Cenozoic times the salt lake and the backwaters probably formed a marine estuary. The barrier having apparently been formed at a more recent period.

At present, if the rainfall should be unusual, and the artificial channels fail to carry off the water of the streams, or if the sea should encroach slightly on the land, a wide estuary of shallow water would be formed and all trace of the salt lake be obliterated.

METHOD OF COLLECTING THE SALT.

The salt harvest is in the hottest part of the summer, in August. The salt lake then is dry and its shallow bed is covered

with incrustations of salt, as it is said to look like a field of snow.[195] The same methods are now in vogue as were employed in 1572. The salt is thrown into heaps and left until spring, when it is shipped for exportation.

The Larnaca salt has been famed from very early times, for its unusual excellence and its reputed medicinal properties.

PRODUCTION.

In 1904 the Island of Cyprus produced 3,954 metric tons of salt.[196] (1 metric ton equals 2,205 pounds.)

Africa

Northern Africa

EGYPT.

There are many lagoons on the northern border of the Nile delta, which extend in a wide curve from Alexandria to the ruins of Pelusium, and are separated from the sea by narrow barriers. The salinity of the lagoons is much reduced by the constant inflow of fresh water from the Nile, yet since ancient times sea salt has been produced from them.[197]

Salt Plains.—To the west of Cairo in the Lybian desert are salt plains, salt marshes and salt springs and lakes. Of the salt plains the most interesting is that of Siwa on the caravan route from Mursuk to Cairo. It is at ancient Ammonium, so called from the temple of Jupiter Ammon. Since the earliest time salt has been obtained there. Herodotus, Eratosthenes and other Greek historians tell that this salt was preferred by the Egyptian priests for their sacrifices to the sea salt, and that the priests carried pieces of the salt in palm-leaf baskets as presents to the kings of Egypt.

In Upper Egypt between the Nile and the Red Sea and to the southward in the Egyptian Soudan in Kordofan, Dar-Fur and elsewhere salt is diffused through the earth in many localities. The chief centers where this salt is refined are Boydha, near Shendi, on the White Nile, and Halfaie, near Sennar, in the valley of the Blue Nile.

195 Prof. Gaudry, Mem. Soc. Geol. France, ser. 2, 1862, 273.
196 Rothwell, Min. Ind., 1906, vol. 14, 512.
197 Von Buschman, Das Salz, vol. 2, 1906, pp. 268-277.

On the banks of the White Nile the salt is generally refined by making two pits in the earth connected by a canal, one pit being at a higher level than the other. The earthy salt is dissolved in the upper pit and the brine flows down into the lower, where it is evaporated. But at Boeydha the earth is heaped up in piles along the street by the Arabs and boiled in great earthern vessels, the residue being re-evaporated in similar jars.

Salines.—In Egypt proper in modern times salt has only been produced on the Nile delta in the salines of El-Meks, near Alexandria, on the western part of Lake Mariut; of Beltim, between Rosetta and Damietta, on Lake Burlus and in the Asiatic salines of Port Said, Balassi and El-Arisch.

Production.—Since November, 1899, the Egyptian Salt and Soda Company, Limited, has leased from the government the right to produce salt. Since that time only the saline of Meks has been in operation, although the company was authorized to produce as much as 1,500 tons from the Baltim saline, but this could only be used for salting fish, as the quality was poor.

The saline of El Meks produces about 50,000 metric tons annually.

Importation and Exportation.—The importation of foreign salt is in general forbidden since 1899, but the Salt and Soda Company is empowered to import salt on payment of the tariff of 8% of the value.

TRIPOLI.

In Tripoli there are many salt marshes and over wide areas the ground is covered with saline efflorescence. But there are very few descriptions of the salt of Tripoli.

In the east of the country there is a zone of bitter salt lakes and marshes, which separates the ancient Cyrenaica from the Lybian desert. These lakes contain layers of salt, gypsum, saltpeter, magnesia and other materials.[196]

In the Fezzan are salt lakes which contain chloride and carbonate of sodium in varying amounts, that of Hahr el Doud being so dense that it looks like syrup. Several hundred tons of soda are sold yearly in the market of Tripoli from these lakes.

[196] Von Buschman, Das Salz, vol. 2, 1906, pp. 300-305.

Along the coast of Tripoli there are a number of sea salines.

No statistics exist as to the amount of salt produced from the salt lakes. The total production of sea salt in 1903 in Turkish Africa was 11,887 metric tons.

In 1902-1903, 800 tons were exported to European Turkey and 4,950 metric tons to Beirut in Syria. Salt is also sent by caravns to the interior of Africa.

TUNIS.

Salt Lakes.—In southern Tunis a depression 240 miles long runs east and west along the northern boundary of the Sahara. This is occupied by a succession of saline basins, marshes and hollows. It extends through Tunis into Algeria, south of the principal chain of Algerian lakes.

The great salt lake of Tunis is the Shott el Jerid or Shott of the Palms, known at its eastern end as the Shott el Fejij. This lake is 120 miles long and lies some 20 yards below sea level. The water is as salt as the Mediterranean. In summer the lake dries up, except in the deepest parts, but even there the water is hidden by the salt crust which covers the entire surface. In walking on this crust one's footsteps echo as on the stones of an archway. Nine or more caravan routes across the lake, some free from danger, but others only to be followed with the utmost caution, owing to the fissures in which the wayfarer may suddenly disappear. The upward pressure of the water from hidden springs forces up the salt crust in cones, which appear as islands in the distance, when seen through the mirage, as hills of salt, although the largest is hardly 20 paces in diameter and not more than three feet above the surface of the lake.

Rock Salt Deposits.—Rock salt occurs at Sidi-Meskine and Djebel Had-Deffa.[199] The Djebel Had-Deffa is a salt mountain on the eastern side of the Shott el Jerid. The salt is as hard and compact as stone, and in general is of a red or purplish color, except where it is washed by rain, where it is snow white and without the bitter flavor of the rock salt.

Sea Salt.—Salt is made from sea water at a number of salines as at La Goulette and Ras Dimas.

[199] Von Buschman, Das Salz, vol. 2, pp. 253-257.

Production.—The salt industry is under State control and the salines are either operated directly by the State or by private companies holding concessions.

In 1904 Tunis produced 23,600 metric tons.[200]

Importation and Exportation.—As the concessions are obliged to export all the salt they produce quite a large amount is sent out of the country. In 1902 salt worth $9,000 was shipped to foreign countries; $6,000 worth was sent to Norway.

No salt is imported.

ALGERIA.

Salt Lakes.—On the plateau of Algeria are many salt lakes known as *shotts* or *sebkhas.* Often their basins lie below the level of the sea.

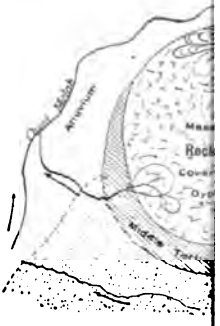
South of Constantine there is a group of small sebkhas of which the most important is El Tarf. Its waters contain 27% of saline materials.[201] The Arabs obtain salt from all these lakes.

South of Algiers there are many salt lakes, the largest being the Shott el Hodna. The most productive are the eastern and western Zhares. The latter, Zahrez Rharbi was observed in April, 1844, by Fournel, when it was simply an immense crust of salt, smooth as ice and looking in the distance like a sheet of water. The salt was two feet thick in the center of the lake and the total amount has been estimated at 250 million tons. It is harvested by the Arabs who camp along the shores. The water is ten times more salt than the sea water and contains no living creatures. The Zharez Shergia contains some 332 million tons of salt. Analyses of the waters of these lakes show a marked similarity to the waters of the Dead Sea, which differs chiefly in its great depth and consequent larger proportion of magnesium chloride and bromides.

The largest of all the Sebkhas of Algeria is the Shott-el-Shergui, 120 miles long.

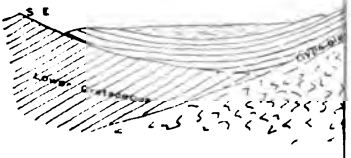
Not far from Oran is the Sebkha of Arzew, a large shallow lake filled by the winter rains and in summer almost completely dry. The salt crust is more than a foot thick and consists of an upper

200 Rothwell, Min. Ind., vol. 14, p. 512.
201 Reclus, Univ. Geog., vol. II, pp. 214-215.



A—SURFACE SKETCH OF THE

B—CROSS SECTION OF THE



C—CROSS SECTION OF A
VILLE,

layer of gray salt and a lower of very pure white salt. The lake is connected by a short railroad with the sea port. The annual production is 20,000 to 30,000 metric tons.[202]

The saline materials of the Sebkhas are all derived from neighboring rock salt beds or saline clays from which the salt is leached out by rains and streams and carried into the lakes.

Rock Salt.—A remarkable deposit of rock salt is the mountain of salt of El Outaia, the famous Djebel el Melah on the east side of the caravansary on the road from El Kantra to Biskra, four hours distant from the Sahara. Coquand[203] found the marls at the base were followed by a thin bed of salt which was overlaid by dolomite, red marls and gypsum with anhydrite. Upon this rested the chief bed of rock salt which is more than 65 feet thick. Above this are heavy beds of gypsum and some marls. In 1896 El Outaia was visited by Tardy [204] who found salt streams flowing down from the center of the salt mountain. Like all the salt mountains of Algeria El Outaia is surrounded by a zone of thermal springs some of which are mineral.

South of Algiers salt deposits occur which are very much like the salt mountain described above. The most striking is that the Jebel Sahari, the Rhang el Melah, on the right bank of the Oued Melah south of Bogar. The salt of this mountain has been mined by the natives for an unknown length of time. Ville[205] describes the Rhang el Melah as a conical hill about 49 feet high. The summit has been greatly eroded and a series of salt ridges and pillars stand like ruins on the crest. The mass of salt is in the center of a Cretaceous outcrop which is surrounded by Miocene strata resting uncomfortably on the older beds. The salt is not stratified but shows bands 3-4 millimeters wide which are of different tints. Ville noticed fragments of marl included in the salt. The gypsum overlying the salt is

202 Fuchs and De Launay, Traite des Gites Min., pp. 521.

203 H Coquand, Bull. Soc. Geol. de France, 2me Ser., vol. 25, 1868, pp. 431-453.

204 Bull. Soc. Geol. de France, 3rd ser., vol. 24, 1896, p. 1075.

205 Ville, "Gites de Sel Gemme du Rhang el Malah," Ann. des Mines, 5th ser., vol. 15, 1859, p. 365.

206 Ibid., Plate 3.

distinctly stratified. A surface sketch and cross section of the Rhang el Melah are shown on Plate LVIII, A and B. The latter shows the salt columns on the crest of the hill which have been protected from weathering by masses of clay.

A salt brook, the Oued Melah, flows from the salt mountain and carries a large amount of saline materials which it deposits in the Zharez shotts. Ville calculated that the the present rate of deposition 5,300 years would be required to form the deposits.

A salt deposit very much like the Rhang el Melah is that of Ain Hadjera, 36 km. southeast of the Rhang el Melah. Its outcrop is nearly circular and is 3280 feet in diameter. A cross section of this salt mountain is shown on Plate LVIII, C. The salt like that of the Rhang el Melah is extremely pure.

South of Oran, Ville describes a salt mine which the Arabs exploited a few miles south of Ain Temushent.[207] The salt lies in gray, schistose clay in the center of a V-shaped fold of grey limestone.

The conical salt deposits of Rhang el Melah, Ain Hadjera and Djebel el Melah have been thought to have arisen from different causes, but the recent explanation is that their origin is similar to that of the Maros-Ujvar salt mass in Austria-Hungary. This is explained as due to the occurrence of a compact mass of salt in Tertiary clays which were later strongly compressed into an anticlinal fold and subsequently truncated by erosion.[208]

Age of the Rock Salt.—Opinions have differed widely as to the age of the Algerian rock salt. It was thought by Coquand to be Eocene,[209] by De Launay to be Cretaceous,[210] by Bertrand to be Triassic and the mountain of El Outaia by Tardy to be Late Tertiary.[211] The Geological Survey of Algeria conducted by the French government reported in 1897 that the salt deposits south of Constantine are found in both the Triassic and Oligocene.[212]

207 Notice Mineralogique sur les Provinces d'Oran et d'Alger, p. 48.
208 Traite des Gites Min., pp. 498, 506.
209 Bull. Soc. Geol. France, 1868, p. 440.
210 Traite des Gites Min., p. 496.
211 Bull. Soc. Geol. France, 3rd ser., vol. 24, 1896, p. 1075.
212 Rapport sur les Travaux du Ser. Geol. de l'Algerie, Ann. des Mines., 9th ser., vol. 15, 1899, p. 193.

Production.—In 1904, salt was produced in the Department of Oran and Constantine from 3 mines (without concessions), 4 brine springs and 12 salt lakes. The total production was 19,000 metric tons of unrefined salt.

In the Department of Algiers the salt is harvested only by neighboring Arab tribes for their own use, and no statistics exist as to the amount produced.

Importation and Exportation.—Algeria imports salt principally from France and French salt enters duty free. Salt from other countries pays the same tariff as that entering France.

The exportation of salt is quite important. Every year over 4000 tons of Algerian salt are sent to the French coast where it is used especially for salting sardines.

Occasionally ships sailing to foreign countries take Algerian salt as ballast.

MOROCCO.

In Morocco there are many brine springs, salt brooks, salt lakes and lagoons and a number of rock salt deposits.

Brine Springs.—The Cretaceous red shales of the plateau region are very saline and give rise to brine springs which are found wherever these red shales occur.[213] The salt springs from the salt lake of Zima, 8 hours journey from Safi, where in summer a considerable amount of salt is obtained from the shallows. The salt is very white and pure and requires no refining. The right to extract the salt is leased by the government to a neighboring tribe. The salt is used almost entirely at Safi.[214]

Near Jabel Hadid the brines are led into shallow pans where the water is evaporated for salt.

In the Atlas mountains brine springs are also associated with the red shales.

Rock Salt.—At Demnat, in addition to brine springs there are extensive deposits of red rock salt. The salt is quarried out in large blocks and sent to the market at Demnat.

[213] Thomson, "Geology of Southern Morocco," Geol. Journ., vol. 55, 1899, p. 197.

[214] Furer, p. 800.

The most important rock salt deposits are north and northwest of Fez, at Muley-Jakub, where the rock salt which is of middle Tertiary age is in open quarries.[215]

Still further north are the salt quarries of M'ghair. Another important salt mine is near Hajar el Wacsif.

Near the coast at Casablanca is a salt hill.

Sea Salines.—At many places along the Atlantic coast as at El-Araish south of Tanger sea salt is obtained and there are also some salines along the Mediterranean coast of Morocco.

Production.—Salt production is carried on chiefly by the natives. It is not a State monopoly and anyone can extract it from the salt lakes or evaporate it from the sea water.

Importation and Exportation.—Only a small quantity of salt is imported, principally fine table salt from England and a few tons that are brought as the ballast of smaller sailing vessels from Spain and Portugal.

No salt is exported to Europe, but a large amount is transported by camels from Morocco to the interior of Africa.

THE SAHARA.

The salt caravans of the Sahara have existed since very ancient times and to this day the traffic in salt forms the principal industry of the desert.

Herodotus about two thousand three hundred and fifty years ago described[216] an ancient caravan route in the Lybian desert which connected salt oases, and he writes that the people living at one of these mines "build their houses all of lumps of salt, since these parts of Lybia are without rain."

Yet there are relatively few salt deposits in the Sahara as compared with other arid regions, but they are very important as they supply the entire Soudan and the Congo Free State. This crude salt in blocks is impure and colored by foreign matter, but is solid, convenient to handle and resists the weather. Thus it is distributed far and wide over the interior. Sometimes the blocks are carried by caravan 1200 miles before reaching the consumer.[217]

[215] Von Buschman, Das Salz, vol. 2, pp. 290-293.
[216] Histories, book 4, secs. 181-185.
[217] Eng. and Min. Journ., March 31, 1904, p. 525.

Salt is produced chiefly at the Sebkha Ijil, Taudeni, Bilma and the eastern slopes of the Tibbu Hills. It is called by the general name of "the salt of the Sahara" and is put on the market in slab or bar form or more rarely is pulverized.

The Sebkha Ijil, lying in the western part of the desert a little south of the tropic, is the source of a large supply of salt. The Kounta tribe own the lake and require payment for every camel load and also levy a tax for the right to extract the salt. Tribes which purchase this right camp around the lake and harvest the salt in the dry season. It is cut into slabs weighing about 54 pounds, eight of which make a camel load. The total amount forwarded annually from Ijil to the Soudan is said to be 20,000 camel loads of about 4,000 metric tons.

The chief market for the salt is the Tishit Oasis among the owners of the lake. Here the people of the Soudan bring slave gangs which are bartered for the salt, three slabs of salt representing the average price of a man.[218]

East of the Sebkha Ijil, on the caravan route about half way from Morocco or Tenduf to Timbuktu, are the rock salt deposits of Taudeni. These have been mined since 1596 and prior to that salt was obtained from Teghasa, 70 miles further north, where the salt seems to have been obtained even before the 11th century.[219]

The salt at Taudeni as at Ijil is cut into slabs. For hewing the salt the workmen used until recently tools made of serpentine. The miners are a half-caste Arab and Negro people who, when the heat is extreme, live in artificial caves excavated in the hills.

In connection with Herodotus' account of the salt houses in the Lybian desert it is interesting to notice that in 1850 Caille, traveling through the Sahara, saw houses built of rock salt at Taudeni and Teghasa.

The third important salt region is on the great caravan route from Tripoli and the Fezzan to Bornu on Lake Tchad. The salt

218 Reclus, Univ. Geog., vol. II, p. 480.
219 Von Buschman, Das Salz, vol. 2, 1906, p. 207.

is at the oases of Kawar, Dirki, Kalala, Bilma and Garu.

Bilma produces the most, best and most valued salt that is sent to the Soudan. Nachtigal found Bilma almost in ruins as a result of the incessant attacks of robbers to which the town is a prey because of its valuable salt deposits. The robbers also often steal the laden camels from the caravans.

The salt is obtained by digging shallow pits of oval shape 10-20 yards long and 6-10 yards wide, surrounded by walls 8-10 yards high that are made from the earth that is thrown out of the pit. The salt pits are irregularly divided by low clay banks into compartments which are filled with water. This dissolves the salt, which lies directly on the surface of the earth, and the water becomes so salty and the evaporation is so rapid that in a few days a crust of salt several inches deep forms on the surface of the water—like ice. Twice a week this salt crust is broken up with sticks or by the Arabs walking in the pools up to their knees in brine and trampling down the crust to stir up the water as much as possible. In general the wind-blown sands and dust mingle with the crystallizing salt so that the salt crust is impure and grayish; but in protected places, pure, white salt forms which can be removed like a coating of ice.

When the evaporation is completed the salt is harvested. The medium quality is made into sugar-loaf or bread-loaf shapes. It is grayish green with a bitter taste and is used partly for seasoning but chiefly for mixing with the camels' food. About ten of these blocks make a camel load. There is also a purer white salt which forms at the bottom of the pits. The medium quality which costs at Bilma $1.00 is sold in the Soudan market for $30.00.[220] For in the Soudan salt can only be obtained by the combustion of certain plants.

As no region off the Sahara produces as much excellent salt as Bilma, buyers come from far and wide and the women often welcome strangers by throwing over them handsful of salt.

Seventy thousand camels come every year for their load of salt at Bilma and some of the salt caravans comprise each as many

[220] Von Buschman, Das Salz, vol. 2, 1906, pp. 205-220.

as 3,000 camels. The amount carried is estimated at from 8,000 to 12,000 metric tons.

Further east, on the southeastern slopes of the Tibbu hills is the fourth group of salt producing localities of the Sahara—Budu, Dimi and Fodi Intêgiding.

At Budu is a salt plain of which an impure salt forms the entire surface. For refining it, water is conducted from near-by springs and the plain is divided into compartments by clay walls as at Bilma. The Budu salt is less pure than that of Bilma and has a bitter taste.

The salt mines of Dimi produce the red rock salt so much valued in the Soudan.

WEST AFRICA.

FRENCH WEST AFRICA.

Brine Springs and Sea Salt.—Salt is made in Senegal, Dahomey and the French Congo.

In northern Dahomey, southeast of the town of Say on the Niger, near the boundary of British Nigeria are the salines of Kalluil (Kaura) in the valley of Fogha. Salt is obtained by taking the saliferous earth from the valley and placing it in funnels made of reeds or straw. Water is then poured on the earth and the brine which flows through is caught in earthen jars and evaporated and a yellowish gray salt is produced. During the rainy season the valley is filled with fresh water and the salt industry is suspended.

On the coast of Senegal at the saline of Gandiole south of St. Louis and on the coasts of French Guinea and Dahomey sea salt is made. In Dahomey recently regular salt farms have been established. Sea salt is also made on the Ivory Coast in the vicinity of Grand Bassam and Assini.

In the French Congo there are brine springs, and north of the river Kouilou is a salt plain where bitter and potassium salts occur with rock salt.

Along the coast of French Kongo sea salt is made under shelters. It is evaporated in specially prepared conical, clay ovens about two feet high, built over slight excavations in the ground. Entire families are engaged in this industry. Some-

times they work through the whole night and the fires of these primitive salines can be seen by far off travelers. The salt is carefully packed in cylindrical baskets and sold to the Bayakas, a tribe living in the interior who come to the coast to trade in salt.

Lenz says that certain tribes, as the Oschebo, who are distant from the coast make salt from the ashes of a swamp plant with large yellow flowers.

There are no estimates of the amount of salt made in French West Africa.

Importation and Exportation.—The French West African colonies import salt from Europe, the Cape Verde Islands and from the Sahara. In 1901, in all, 7,589 metric tons. The tariff ranges from 15 cents to 72 cents per hundredweight. In the western Kongo and the Tchad territory the tariff is 10% of the value. The European salt is chiefly from France, but some is also introduced from Germany and Portugal.

Salt is exported into the interior, where it rises greatly in value. So in Gabun, on the coast, the selling price in 1904 was 2½ cents a pound, while at the market of Niele in the Soudan the same amount was worth 85 cents.[221]

BRITISH WEST AFRICA.

Sea Salt.—Very few recent facts exist in regard to salt production in British West Africa.

On the Gold Coast, near Adda, salt is made in a lagoon at the mouth of the Volta River, and east of this on the Slave Coast, in the lagoon of Kitta.[222]

Along the coast of Sierra Leone and on the Island of Sherbro and on the Gold Coast, especially near Anamabo, sea salt is obtained by the natives in the following way. During the spring and fall equinox the low coastal plains are flooded and a fine mud is deposited. As soon as this is dried by the sun it is scraped up by the natives and dissolved in large earthen jars. The brine on evaporation gives an excellent salt which is preferred to sea salt, although it is not so white.

[221] Von Buschman, Das Salz, vol. 2, pp. 262-265.

Many slaves are employed in the salt industry on the Sierra Leone coast, which are obtained from the interior in exchange for European wares and salt. Salt is so valued by the tribes of the inner plateau country that if they have no slaves for sale they will sell their families and all they hold dear for salt. Thus salt is the principal article used in the purchase of slaves.

Plant Salt.—On the right bank of the Benue River, the principal tributary of the Niger, there are several salines, as the Sebkha of Keana. On the left bank some plant salt (see page 247) is made, although the introduction of Sahara salt has greatly lessened this industry. In the negro village of Yangfulli special conical ovens are used in which a kind of grass (*burabaia*), which grows on the valley plains, is burned. The ashes are mixed with water and the solution on evaporation gives a bluish grey powder which tastes strongly of potassium salts. Plant salt is made at many other villages but the plants are usually burned on the open ground.

In the vicinity of Benin plant salt is made from a willow-like shrub called the salt bush, which grows in the coastal lagoons.[223]

Importation and Exportation.—Besides a considerable amount of Sahara salt, salt is also imported into British West Africa from England and Germany. Sierra Leone alone in 1901 imported 3,746 metric tons. The tariff in Sierra Leone is 8 shillings per English ton, in Gambia 5 shillings, on the Gold Coast 2½ shillings, and in Nigeria ½ shilling.

Salt is exported into the interior chiefly in canoes up the Volta and Mono rivers. At all the trading posts salt serves as money.

LIBERIA.

In past times a small amount of sea salt was made near Cape Mount, northwest of Monrovia, and at present some salt is made between Sinoe and Cape Palmas.[224]

But nearly all the salt used in Liberia is imported, chiefly from Germany and Austria. The tariff is 5 cents per hundred-

[223] "Com. Geog. of Yoruba," Proc. Roy. Geog. Soc., vol. II, 1889, p. 626.

[224] Von Buschman, Das Salz., vol. 2, p. 299.

weight. In 1904 salt cost 80 cents to a dollar per hundredweight in Monrovia.

There is little or no exportation of salt inland.

SPANISH POSSESSIONS.

A small amount of salt may be made along the coast of the Spanish possessions, but the greater part of the salt used is imported. On the Island of Fernando Po salt, next to rum and tobacco, is the costliest of European wares.

KONGO STATE.

Salt Mine.—Near the junction of the Kongo with its tributary, the Kwango, Boshart states that there is a salt mine which supplies the region far and near with salt. There are also weak brine springs, but the salt obtained from them is impure.

In the southeast of the Kongo State there are the warm brine springs of Moachia, near Katanga. The temperature of the water is 36° to 40° Centigrade. The Syndicate of Katauga has developed an important industry in the evaporation of salt from these springs.

North Katanga, between Kilemba and the village of Munza, salt is obtained by the negro tribes from the salt plain. This plain is entirely sterile as salt is diffused through the soil and all the springs and marshes are salty. The natives construct funnel shaped frames of sticks carefully lined on the inner side with large leaves and the small end is closed with a filter of grass. The funnel is filled with the salty earth and boiling water is poured on. The brine which filters through the grass is caught in gourds or earthen jars. On evaporation this gives an impure salt with usually a large percentage of saltpeter. It is made into cones weighing about 3 pounds each and is eagerly sought by the tribes that have no salt.[225]

In the northeast of the Kongo State, Enim Pasha saw large fragments of salt from Mabode-Land. They were fairly white and pure, but had a slightly bitter taste.

Importation and Exportation.—The greater part of the salt used in the Kongo State is imported. Sahara salt is brought in from the north and European salt from the coast. Some of

[225] Von Buschman, Das Salz, vol. 2, 1906, pp. 266-268.

the European salt is carried far inland and Stanley saw European salt for sale in the market of Njangive, on the Upper Kongo.

The tariff is 10% on the value.

There are no statistics of the production or exportation of salt.

PORTUGUESE WEST AFRICA.

Rock Salt.—In Angola there are rock salt deposits in the Permian-Triassic beds, which are exploited by the natives at Kuanza and Karoko.[226]

The salt mines of Ndemba in the territory of the Kissama tribe were described by the earliest explorers. In the account of the campaign of Continho in 1602 we read: "In this place there is such a store of salt that most of the country is perfect clear salt. * * * It is some three feet under the earth, as it were ice, and they cut it out in stones of a yard long, and it is carried up into the country and is the best commodity that a man can carry to buy anything whatsoever."[227]

In connection with this early account it is interesting to note that Andree says that at the trading posts salt is brought from Kissama and circulates as money.

Sea Salt.—Sea salt is made on the northern and southern coasts of Angola, but this industry is much more important on the Cape Verde Islands, especially on the Islands Sal, Boavista and Mayo. On the Cape Verde Islands salt making is not a monopoly and is carried on chiefly by private enterprise, the State has, however, some salines on the Island of Mayo. In 1904, 60,000 metric tons of salt were produced in the islands.

Importation and Exportation.—No salt is imported on the islands, which principally supply the Portuguese possessions on the mainland. A small amount is imported there from Portugal and England.

The Cape Verde Islands also export a considerable amount of salt to North and South America, and many ships voyaging to the Orient get their supplies of salt from these islands.

226 Das Salz, vol. 2, pp. 293-297.
227 Adventures of Battell in Angola, London. pp. 36-37.

GERMAN WEST AFRICA.

Sea Salt.—On the coast of Togo very little sea salt is now made, although it was formerly an important industry, but the coast is not well adapted to it. Much less sea salt is made in the German West African possessions than in the English Gold and Slave Coasts and the French Dahomey Coast.

At Daboja, in Togo is a salt swamp from which the negroes make a gray salt.

In Adamawa, especially at Bubanjidda, plant salt is made (see page 247), but in the southern part of Kamerun there are brine springs.

In German Southwest Africa salt valleys and salt pans are very common on the plain between Ovambo-Land and the hills of Damara-Land eastward to the Kalahari Desert. The salt obtained from these pans is so impure that it is only used by the natives and is called negro-salt.

One of the largest of these pans is the Etosha pan, two and a half days' journey from Ondonga. This immense salt swamp is white as a frozen sea. At its western end is another pan which was visited in 1900 by Mr. Speak, an English engineer, who described it as a shallow, oval pan without inlet or outlet, about two miles wide. The floor is covered with a crust of salt 12 to 15 cm. thick, beneath which is a black mud of unknown depth. Samples of this were analyzed and found to contain 94.7% sodium sulphate. The black mud is therefore an impure glauberitic salt, while the upper crust is 90.4% sodium chloride. Potassium is wholly lacking.

Importation and Exportation.—No estimates exist of the amount of salt produced in German West Africa. Most of the salt is imported, chiefly from Germany, but some Sahara salt finds its way into northern Kamerun.

Part of the domestic salt and some of the imported salt is transported into the interior.

The salt is shipped up the Volta and Mono rivers in canoes to Kratji, which is the principal salt market. That designed for caravan transport further inland is packed in loads weighing about 44 pounds. The value of such a load near the coast is 88 cents, which rises to $2.50 in the interior.

Any locality where salt can be obtained becomes a natural trade station where salt serves as money. In fact, salt is the only currency which is always accepted throughout the regions of the interior.

CENTRAL AFRICA.

SALT MANUFACTURED FROM PLANTS.

Many thickly populated regions of Central Africa, especially in the southern Soudan, have no domestic salt and rarely or never obtain imported salt. In these places a substitute for salt is made from the ashes of certain plants. Various species are used for this purpose as *Sorghum vulgare* and other tall grasses, and plants of different genera, among them *Salvadora persica, Borassus flabelliformis, Grewia mollis and Pistia stratiotes.*[228]

The plants are burned to ashes, which are placed in perforated earthen vessels into which water is poured. The solution which flows through is evaporated over fire and gives a gray residue, which tastes of saltpeter. This is re-evaporated several times and finally a weak potassium salt is obtained. An analysis of the plant salt prepared by the negroes in Nbangi gives the following result, in which there is no trace of common salt:

Potassium chloride	67.98
Potassium sulphate	28.73
Potassium carbonate	1.17
Insoluble matter	1.65

The negroes have learned to select plants with a small percentage of potassium carbonate, as otherwise the salt would be too caustic for use.

RARITY AND COSTLINESS OF SALT.

In many parts of Central Africa salt is so costly that to say a man eats salt with his food is to say that he is a rich man. For in Central Africa, as in the interior of Madagascar, salt is a rare luxury, used only by princes and the wealthiest people.

The amount of salt theoretically necessary for every person is about 12 pounds a year, and many travelers in Africa have

[228] Von Buschman, Das Salz, vol. 2, pp. 212-213.

told of their suffering for lack of salt. Mungo Park, after traveling among negro tribes and going without salt for a long time, says that when he finally passed through a salt market his longing for salt was so great that he could not paint it in words. And Nachtigal describes how a handful of Bilma salt, that he had happened to keep on his journey into Central Africa, became a valued treasure of which he daily ate a pinch or so. Rohlfs relates that on Lake Tchad the need of salt was so great that the negroes did not wish to buy glass beads or corals, but salt, always salt. The entire lack of salt in many tribes seems to produce chronic disease.

So great is the desire for salt that parents will gladly sell their children, brothers their sisters, and husbands their wives into slavery for the sake of a few handsful of salt.[229]

EAST AFRICA.

ITALIAN POSSESSIONS.

Salt Plains and Salines.—In Eritrea there are a number of salt lakes and depressions along the coast in which salt layers are formed, but little or no salt is extracted from them.

Most of the salt in Eritrea is obtained at the saline of Asale, on the great salt plain which is chiefly in Abyssinia and is described on page 249. The yearly output at Asale is 15,000 metric tons.[230]

Salt is also produced at the natural salines of Bardoli, south of Massawa, which produces about 7,500 metric tons annually, and of Hasmat, north of Massawa, which produces some 300 tons. An Italian company has recently been incorporated for the development of the rich natural salines of Asmara.

In Somali-Land, on the coast to the west and south of Cape Gardafui, there are sea salines.

Only a very small quantity of refined salt is imported into Eritrea as the colony produces enough salt for its own use. The import tax is 8% of the value.

Salt is exported from Eritrea principally to Abyssinia and Arabia, and from Somali-Land to the Island of Zanzibar and German East Africa. The amount exported is not known. Salt

229 Das Salz, vol. 2, 1906, p. 220.
230 Von Buschman, Das Salz, vol. 2, pp. 305-307.

is transported into the interior on pack animals and along the coast on boats.

The price of salt increases with the distance inland. In 1903, in Eritrea the average price of coarse cooking salt was 1 cent a pound, but at the market of Lugh, where, as elsewhere in the interior of Somali-Land, there is no money, 1 chela of salt is worth the same amount of negro corn (*Sorghum vulgare*).

ABYSSINIA.

Salt Plains.—The great salt plain of Abyssinia is on the plateau of Afar, west of the town of Amila, on the coast of the Red Sea.

The salt extracted from this plain, like that from Lake Assal, is cut into pieces, which are described by some travelers as 8x1½ inches in size, tapering at both ends, like a whetstone; and by others as prisms 11 to 12 inches long and 1½ inches thick. The pieces weigh about 1½ pounds.

The explorer, Coffin, after a journey of some 50 miles from Amfila westward, came to the borders of the salt plain. He was there provided with a special kind of sandal made of palm leaves, which all who cross the salt plain must wear. The width of the plain is four days' journey. For the first half mile the salt is soft, it then becomes hard and crystalline like ice on which snow has fallen and frozen after it had partly thawed. Here and there masses of pure salt rise from the surface like branching *Madrepora* coral.

After Coffin had traveled five hours across the plain he came upon Abyssinians extracting salt with axes, in the shape of whetstones. The salt is in horizontal beds and is easily won. To a depth of about two feet from the surface it is hard and pure; then it becomes coarse and softer and only hardens after it has been exposed a certain length of time to the air. Below a depth of three feet it is too earthy for use. Only a few points on the plain have been explored, but there is such a great amount of salt that the whole of Abyssinia and the neighboring countries could easily be supplied.

Quarrying the salt was formerly very dangerous, because of the frequent attacks of a hostile tribe, so that only the poorest and lowest of the natives were employed. The salt caravans on

their way from the plain to the town of Antola were often attacked and the leaders of the caravans held a position of great honor and importance, for the prosperity of the country depended largely on the safe arrival of the caravans.[231]

Production.—In 1900 the salt produced in Abyssinia was estimated at 14,000 metric tons[232] (one metrict ton equals 2.205 pounds).

Importation and Exportation.—Some sea salt is imported from the coast of the Red Sea and the Gulf of Aden, and a small amout of foreign refined salt is used in Abyssinia.

It is quite possible that some salt is exported to Egyptian Soudan, but there are no estimates of the amounts imported and exported.

Salt as Money.—In Abyssinia until lately there were no small coins and pieces of salt were used as money. According to Von Buschman,[233] this salt currency is still in use. The whetstone-shaped pieces of salt are called *amoulies* (*amoudi, amulet, amole*, etc.). The value of an amoulie at the place of production is much less than in the interior. Thus where the salt is extracted 80 to 100 amoulies are worth $1. In Sokota, the chief salt market of Abyssinia, 60 to 80 have the same value; in Adua, 48; in Gondar, 20 to 30; in Debra Tabor, 15 to 20, and near the Soudan, as in Fadasi and Baso, 4.

Salt is so highly prized that the Abyssinians carry pieces with them to offer a taste to those whom they wish to meet as friends.[234]

FRENCH EAST AFRICA.

Salt Trade.—In French Somali-Land, near the Gulf of Tajura is Lake Assal, 48 miles southwest from the town of Tajura. The salt extracted from this lake is cut into small pieces the shape of whetstones and is exported to Abyssinia, especially to Schoa, where it is used as money.[235]

231 Natural History of Salt, London, pp. 134-135.
232 Mines and Quarries, 1903, pt. 4, p. 362.
233 Von Buschman, Das Salz, vol. 2, 1906, pp. 287-290.
234 Universal Encyclopedia, vol. 10, 1902, p. 273.
235 Von Buschman, Das Salz, vol. 2, pp. 262-265.

In Madagascar there are salt swamps and hot springs on the southeastern coast, and on the west coast near the mouth of the St. Vincent River salt is obtained from a lagoon, where it evaporates naturally. This salt is thought to be derived from a rock salt bed near the surface. The principal harvest is made by the natives in the dry season, when the floor of the lagoon is covered with 2 to 6 inches of pure salt. At every harvest 300,000 pounds of salt are won.

Similar but smaller lagoons occur along the coast elsewhere on the island.

Sea Salt.—Some sea salt is made along the coast, and at the Paris Fair, in 1900, sea salt was exhibited from the northern coast of Madagascar.

Plant Salt.—In the interior of Madagascar, where salt is extremely scarce, the natives make a substitute for salt from the ashes of a species of palm. According to Von Buschman, this plant salt forms an important article of trade.

Salt is imported from Europe, especially from France. A small quantity is also brought in from Persia and Arabia. In 1901, 2,994 metric tons were imported to the Islands of Madagascar and Réunion, of which 2,960 were from France.

The tariff on salt entering these islands is the same as that of France, but salt enters the Somali Coast duty free.

Most of the salt exported is that sent from Lake Assal to northern Abyssinia.

BRITISH EAST AFRICA.

In Uganda there are several salt-producing localities, of which the most important are Katwe, near Albert Edward Nyanza, and Kibero, near Albert Nyanza. Many battles have been fought for the possession of these places.

Salt Lake of Katwe.[236]—Stanley describes the salt lake of Katwe, or Mkijo, as the natives call it, as about 5 km. long and a yard deep. He saw in pits, dug in the sand in which water had been led and evaporated, beds of crystalline salt. This on analysis gave a percentage of 82.71% chloride of sodium, 8.43% of potassium sulphate and small amounts of other minerals.

[236] Darkest Africa, vol. 2, p. 311.

The marked peculiarity of the lake is its blood red color. The inhabitants of Katwe live on the sale of the salt from this lake and that of a smaller one to the southeast. As the salt is eagerly bought by the surrounding tribes it is very valuable.[257]

Before continuing into the interior, Stanley provided himself with salt from Katwe and a hundred natives were busy the whole afternoon getting the salt. The people go out into the lake about 100 yards, where it is knee-deep, and lift out lumps of the salt which they carry a short distance overland to the canoes in Albert Edward, or to the caravans.

Salt is won on the eastern shore of Albert Nyanza at Vacovia, where saliferous earth is mixed with water and evaporated in earthen jars. Saliferous earth is refined in a similar way on the Island of Nyamasassi.

But the chief salt industry of Albert Nyanza is further north. in the valley of Kibero. There salt is produced which supplies the whole northern part of Unjoro over to Mruli and a large part of Uganda.

Hot Brine Springs.—Emin Pasha says that not an inch of cultivated land is to be seen near Kiburo, as all provisions are brought in from over the mountains. The all-absorbing industry —not of the men, for they are very lazy, but of the women—is winning the salt. This is obtained at a place about ten minutes' walk east from the edge of the lake, where there is a crescent-shaped valley, which is full of rock débris, except where it has been cleared by the women. The stones are so hot that they cannot be touched with the hand. Many hot brine springs, 85° to 90° Centigrade rise from the heated floor and escaping gases fill the air. Steam rises on all sides from the superheated water and the atmosphere is like that of a steam bath. But from the activities going on in this veritable Devil's kitchen, one would imagine oneself in a gold placer mine, and indeed for the natives salt is gold. Where stones have been removed the hot brine is led in rills in all directions so as to saturate as much of the earth as possible. Each worker's field is separated off by a low wall of stones. Everywhere women and children are at work

257. Von Buschman, Das Salz, vol. 2, pp. 237-246.

scraping up the salty earth or mixing it with water and putting it in the filters, which are perforated clay vessels raised up on three stones, so that the escaping brine may drip into smaller jars beneath. The brine is then either evaporated in the open air and a white salt obtained, or it is boiled in the huts which makes a darker and less pure salt. The art of the women who make the salt lies largely in the proper mixing of earth and water before filtering.

The salt is generally of a dark color and of a slightly bitter flavor. It is packed for sale in cylindrical packages wrapped in dried banana leaves. Such a package, which weighs about 25 pounds, was worth, in 1880, 400 cowry shells (*Cypraea moneta*), which represent about $1.30. The salt is also traded for ox-hides and the skins of large antelopes and for *Durrah*, or native corn (*Sorghum vulgare*), and raw iron, glass beads and other wares.

Further north from Alberta Nyanza salt is also made from saliferous earth in several places, but in much less quantity.

Plant Salt.—As not nearly enough salt is made to cover the demand in eastern equatorial Africa, substitutes for salt are made, as from the ashes of grasses.

Sea Salt.—On Mauritius some sea salt is made, but not enough to supply the island.

Importation and Exportation.—A large amount of foreign salt is imported, chiefly from English Somali-Land and from Aden and other places on the Arabian coast. Salt is also brought from Cape Colony, England, Germany and France. No estimate is possible of the total amount imported.

A small quantity is exported to northern British South Africa and to Madagascar.

GERMAN EAST AFRICA.

Salt Springs, Steppes.—In German East Africa there are extensive salt steppes and salt lakes and brine springs which have been used for the production of salt by the natives for many years.

In the province of Usambara there are salt steppes south of Mount Kilimandjaro.[333]

[333] Von Buschman, Das Salz, vol. 2, pp. 281-286.

South of Mount Kilimandjaro is Lake Manyara, along the shores which are encrusted with salt are a number of hot springs, some with a temperature of 80° Centigrade. The plain south of the lake is very saline and is no doubt the floor of a former salt lake, which was an extension of the present Lake Manyara. Analyses made of the salt from Lake Manyara and the brines on its shores showed the presence of a large percentage of impurities, yet the negroes always mix it with their sorghum bread.

According to Von Buschman, a much purer salt is obtained further south from the saliferous earth of Irangi, and salt is won from salt steppes and small salt lakes in a few other localities.

But most of the salt used in the colony is made from the brine springs in the province of Uvinza, which is near Lake Tanganyika. This salt is shown by analysis to be 95.57% sodium chloride. A company has lately been incorporated which purposes to supply all the Central African region with salt from the Uvinza brines.

Plant Salt.—Where no salt can be obtained the natives make plant salt from the ashes of the reed grasses, which are burned on the steppes every year. This substitute for salt is made in a number of villages, as for example in Rugago, in the province of Makena.

Importation and Exportation.—Salt is imported chiefly from India, Persia, and Arabia, the Somali-Coast and Cape Colony. The imported salt is nearly all sea salt, which is brought in bulk as ships' ballast, and is packed in sacks on the coast. A small amount of table salt is brought in from England. The total amount annually imported is about 2,860 metric tons.

Some salt is exported. The export tax is 10% of the value.

PORTUGUESE EAST AFRICA.

Rock Salt Springs.—In Mozambique,, Lorenzo Marquez and the other Portuguese dependencies no rock salt deposits have been discovered; but Karsten states that in the whole valley of the Zambesi there are salt springs, salt streams and salt lakes.

The earth is saliferous along the banks of many rivers as far as the waters are brackish and the negroes make a large quantity of salt for their own use by filtering and refining this soil.

Sea salt is made along the entire coast, but particularly near Mozambique and Quilimane, which is north of the mouth of the Zambesi.

Von Buschman states that in a saline at Idugo in the region of Angoaze the "Companhia da Zambezia" produces annually about 10,000 sacks of sea salt, each sack weighing 60 pounds, which would make 300 metric tons. In this saline ten negroes and two white men are employed.

Importation and Exportation.—The very high tariff practically prevents the importation of foreign salt and all the salt brought in is either from Portugal or the Portuguese colonies.

Some salt is exported from Mozambique to Natal.

The wholesale price of a 60-pound sack of salt in Quilimane, in 1903, was 400 reis.[239]

SOUTH AFRICA.

In South Africa salt is obtained from salt lakes (salt pans) and salt marshes (salt vleys), which occur along the coastal region and also far inland. The salinity of the coastal pans is apparently derived from the sea, but no adequate explanation has been given of the inland salt pans.

COASTAL SALT PANS.

In Cape Colony there are a number of salt pans and salt vleys not far from Cape Town. These are usually separated from the sea by a belt of sand dunes. Among the most important is the salt vley of Muizenberg, on the east coast of the Cape peninsula. North of Cape Town, in Zwartland, the water is so salty that only those who are accustomed to it can drink it.

In the district of Swellendam is a large salt pan and the encrustation along the shores are harvested.

Eastward in the region of Algoa Bay, near Port Elizabeth, are two salt pans at Bethelsdorp and Zwartkops.[240] The company that owned the former has lately failed. The latter, which

239 Von Buschman, Das Salz, vol. 2, pp. 297-299.
240 Von Buschman, Das Salz, vol. 2, pp. 221-233.

is called the *Grootpan,* is two miles east of the Zwartkops River and lies about 90 yards above sea level. It furnishes an excellent salt very like the English salt of Worcestershire. For many years it has been controlled by the Zwartkops Saltpan Company. The Grootpan lies in the midst of a deep forest, like a snow field that gleams and glitters in the sunshine, with a lake in its center, of deep blue water.

The salt is harvested from November to April by some 150 workmen, who scrape it up with spades and wooden rakes and pile it in heaps to dry. The lake is a nearly regular oval, 1,500 long and 1,000 yards wide. When it is full after a heavy rain it is about two feet deep. It is fed by brine springs, which cover the entire floor, with a salt crust that is strong enough to support the weight of the workmen. The salt that is removed is thus constantly being made up for by fresh deposits. Salt has been extracted from the Grootpan since the time of the earliest colonists and before that it had been used by the natives. The present daily production while the harvesting is going on is 300 tons. The salt is packed in 200-pound bags for sale, and is graded as coarse, medium and fine. The company has lately run a branch railroad to the pan so that the salt is now transported by rail, instead of by ox-cart, as formerly.

INLAND SALT PANS.

In the Kalahari Desert[24] the salt pans and salt vleys serve as licks for hundreds of wild antelopes. And in many localities the Bushmen and other tribes living near produce salt in a very primitive way for their own use and for trade with tribes in the interior.

In the Great Karroo region are many similar saline depressions and a salt stream which, according to Barrow, is as salt as the water of the English Channel.

Near the Orange River, where the country is exceedingly arid, in a tract of land called the Panne-veld, are a great number of salt pans. They are all more or less circular and vary in size from a few yards to several miles in diameter. The exact com-

[24] Passarge, S., Die Kalahari, Berlin, 1904.

position of the salt is not well known, but sulphates of calcium and magnesium are present, as well as the chlorides.[242]

PRODUCTION.

From the salt pans, which are distributed in 17 Divisions, of which the largest are in Cradock, Ceres, Hopetown, Port Elizabeth, Prieska, Uitenhage and Malmesburg, the total production was, in 1903, 15,113 tons.[243]

No salt is produced in Natal or in Zulu-Land.

In the Transvaal and Orange River Colony there is a large amount of salt in salt pans, especially in the northern Transvaal. But, according to the Government Mining Engineer, salt is extracted from only one of these pans, which belongs to the Zoutpans Berg Salt Company. The region is so unhealthy that salt can be obtained from this pan only during the winter. In 1902-1903, 770 tons were produced.

In the interior of South Africa there are many places where salt is obtained by Kaffirs, Hottentots, Bushmen, Bechuanas and Matabeles for their own use and for trading with tribes to the northward that are without salt.

IMPORTATION AND EXPORTATION.

The tariff on all but English salt is 10% of the value; on English salt it is 7½%. The salt is imported chiefly from England and some also from Germany, Belgium and Mozambique. In 1904, 8,794 tons were imported from England.

A small quantity is exported to German Southwest Africa.

AUSTRALIA.[244, 245]

GENERAL OCCURRENCE OF SALT.

The western interior of Australia is occupied by the Great Sandy Desert, in which there are a large number of salt lakes

242 Rogers, A. W., Geology of Cape Colony, 1905, pp. 386-387.
243 Mines and Quarries, 1903, part 4, p. 334.
244 Von Buschman, vol. 2, pp. 481-497.
245 Furer, Salzbergbau, pp. 310-311.

and marshes. Another group of salt lakes lies in a series of depressions not far from the southern coast. Of the latter the most important is Lake Torrens.

Most of these lakes, however, contain bitter salts, as well as sodium chloride, and as a rule no attempt is made to refine the salt. But in South Australia, where the production of salt has become an important industry, there are salines at several salt lakes, as at Lake Fowler and Lake Torrens. The salt lakes belong to the Crown and are leased to private companies at 25 cents per acre.

SEA SALT.

Sea salt is also produced especially in South Australia at Port Adelaide and on York Peninsula, where there is a large salt refinery.

In Victoria there are four sea salines, which produced in 1904, 2.781 metric tons.

In West Australia, on the small island of Rottnest, near Fremantle, there are sink holes, or depressions, which become filled with salt water in winter. These lakes dry up in summer and leave encrustations of salt that are remarkable for the size of the crystals, which are octahedrons fully an inch long. About 100 to 125 metric tons are annually produced in this saline.

ROCK SALT.

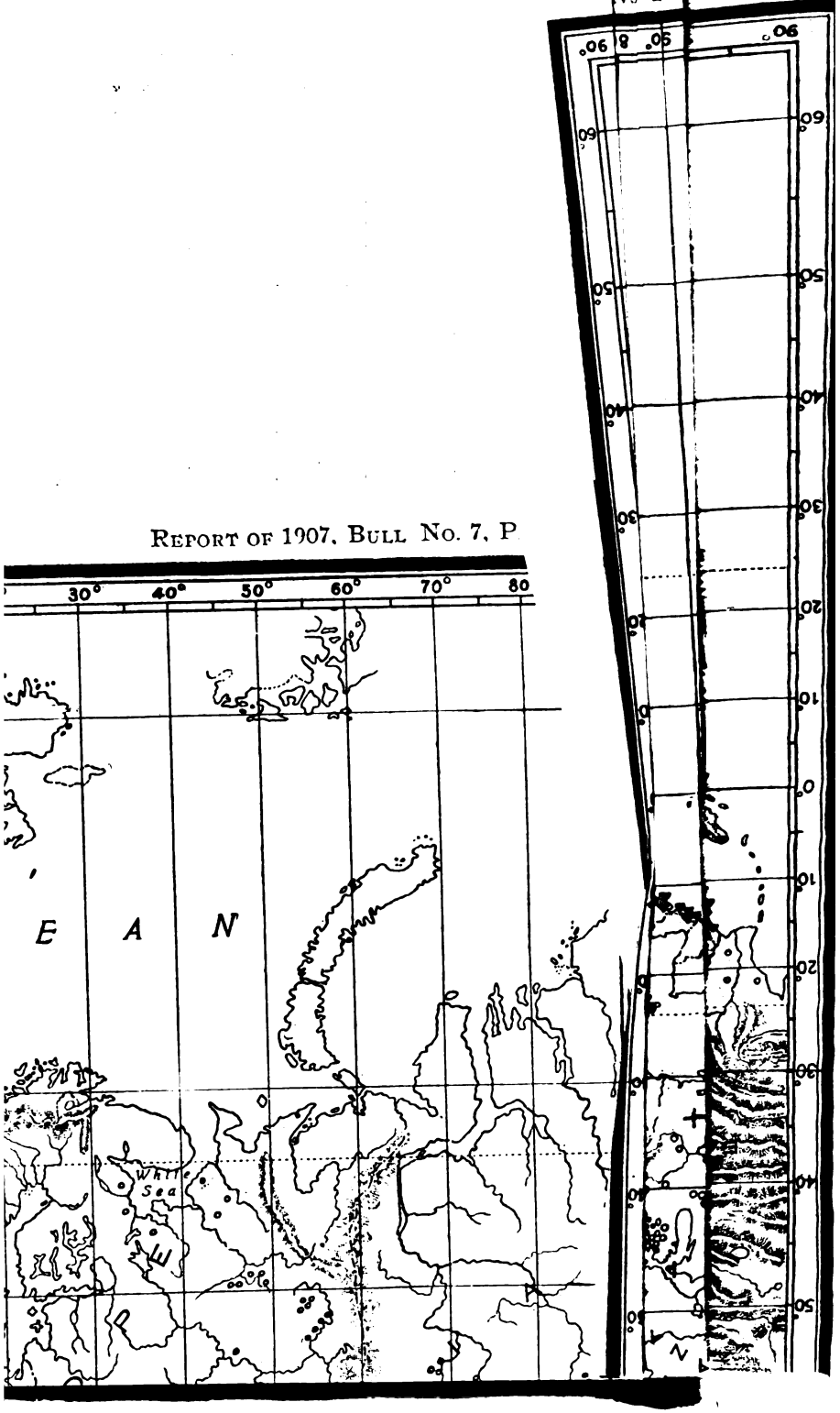
In New South Wales there are small, local beds of rock salt, but they are of no economic use.

PRODUCTION.

In 1904, South Australia and Victoria produced 43,423 metric tons, of which 93% was made in South Australia.

IMPORTATION AND EXPORTATION.

Colonial salt enters Australia duty free, and so does brown rock salt and salt for agricultural purposes. The tariff on foreign salt is $2.95 per metric ton for ordinary salt, and on table salt it is 15% of the value.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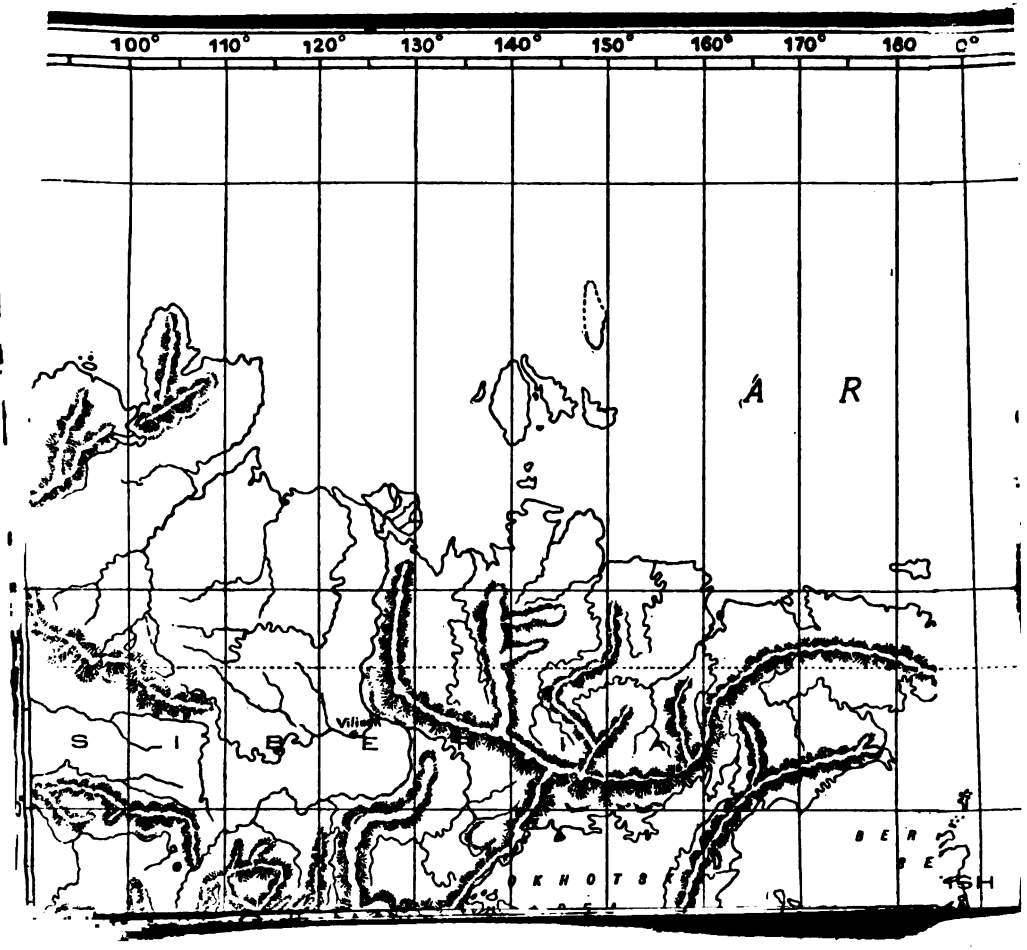
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Salt is imported chiefly from England and in small quantities from Germany.

In 1903, the wholesale price of salt in Melbourne was $17.73 per metric ton, but the retail price was $33 for the same amount. In general the retail price of salt in Australia is from two to four times the price of the wholesale rate.

NEW ZEALAND.

In New Zealand there is no salt except that which is contained in some of the mineral springs.

Salt is imported from England, and in smaller quantities from Germany and the United States.

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BULLETIN NO. 8 **REPORT OF 1909**

GEOLOGICAL SURVEY of LOUISIANA

G. D. HARRIS, Geologist-in-Charge

OIL AND GAS

in

Northwestern Louisiana

With Special Reference to the

CADDO FIELD

By G. D. HARRIS, Geologist, and
I. PERRINE and W. E. HOPPER, Asst. Geologists

Made under the direction of the Louisiana Experiment Stations, W. R. Dodson, Director

BATON ROUGE
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PREFATORY REMARKS.

During the last session of the State Legislature a small sum of money was appropriated for finishing the Survey work already more or less in hand. But after paying the printing bills on reports in press the sum left for investigation was very small. However, a few months were spent in the field during the fall of 1908 by the writer and Mr. Perrine. An appropriation of $1,500 was made by the United States Geological Survey, permitting not only more work to be undertaken by the persons just mentioned, but also the hiring of Mr. Hopper, who remained in the field till the middle of February, 1909.

In preparing this very preliminary statement we have drawn freely upon the facts obtained both by State and National funds. The brevity of this report is owing to the need of some information on the subject at once. Again our State funds are not in a condition to admit of attempting to publish a more detailed report. Such a paper is, however, being prepared for publication by the United States Geological Survey.

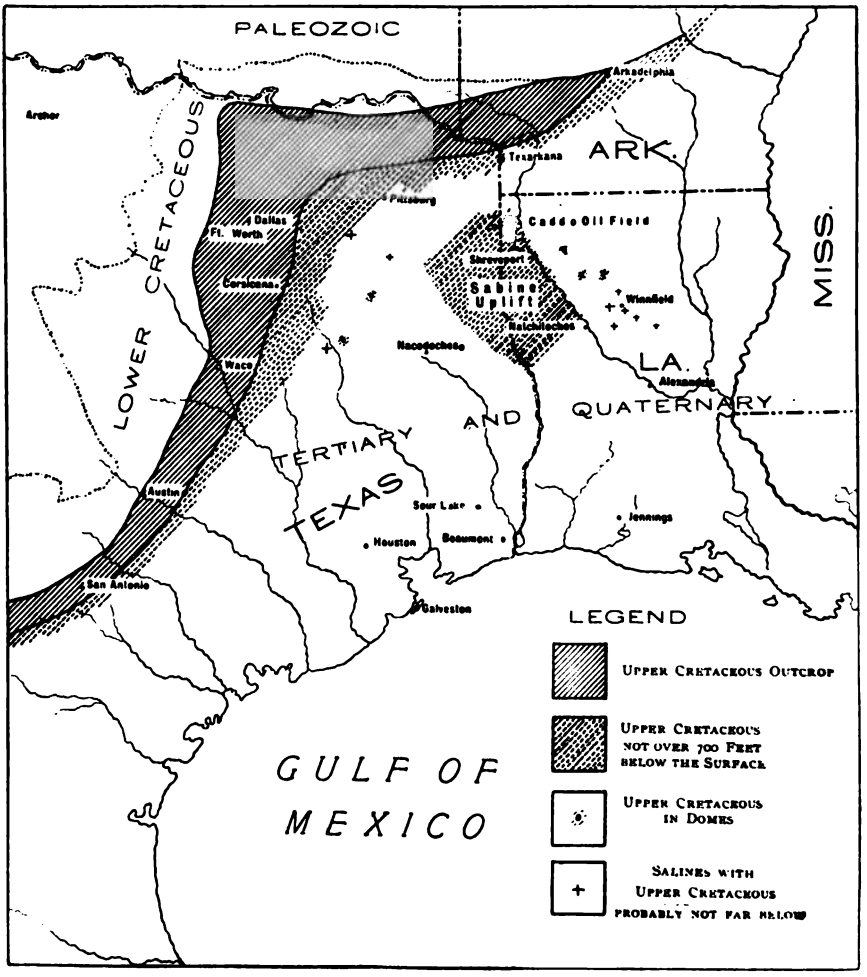

PLATE I. The northern outcropping of the various Upper Cretaceous (gas and oil-bearing) beds, is indicated by diagonal ruling. As they dip beneath the younger Tertiary and Quaternary beds to the southeast, and before they are covered by more than 700 feet of such later deposits, their location is indicated by broken lines. By extensive crustal movements, in the vicinity of the "Sabine Uplift" these Upper Cretaceous beds have been brought up near the surface, as indicated. For a discussion of the lesser uplifts, "domes," see Bull. No. 7 of this Survey.

OIL AND GAS IN NORTHWESTERN LOUISIANA, WITH SPECIAL REFERENCE TO THE CADDO FIELD.

STRATIGRAPHY OF NORTHWESTERN LOUISIANA.

We cannot here go into the history of the development of our knowledge of the stratigraphy of northwestern Louisiana. It may be gathered, however, by a perusal of our previous State papers, or, better still, from our forthcoming report to be published by the United States Geological Survey. (Report of '99, Part I; '02, pp. 1-16; '05, pp. 260-457; '07, pp. 60-150.)

The map shown as Plate I and the sections on Plate II indicate the outlines of the stratigraphy of the northwestern part of Louisiana and the adjacent areas of Texas.

Systems of Rocks.—We have here to deal with three systems of rocks: the Cretaceous, Tertiary and the Quaternary. Of these the Cretaceous occupies the lowest place stratigraphically, and was first deposited. Its rocks are more or less consolidated (hard) and contain, by the way, all gas and oil horizons of this region. Next above come the Tertiary clays and sands and large boulder-like concretions. Finally, near and at the surface generally, Quaternary clays and sands occur. In drilling a well the youngest, uppermost beds are first penetrated, then successively older beds are passed through so long as drilling is continued.

Structural Peculiarities.—The distribution of these various systems, together with the still older and underlying Paleozoic rocks, from Arkansas southward, and west of the Mississippi may be seen by consulting Plate I. An attempt is made on this map to show certain irregularities in the Cretaceous rocks whereby they are raised in certain places near or to the surface, whereas without these irregularities they would be buried hundreds or thousands of feet beneath Tertiary deposits. Plate II, A, will help to convey the same idea. Notice that if the Cretaceous beds beneath Texarkana continued to dip southward at the same rate till the Gulf was reached they would be many times deeper beneath the surface than they doubtless really are. In fact, at Vivian, a reverse or north dip of high angle occurs, bringing the Cretaceous beds within 700 or 800

feet of the surface. Then, to the south, to beyond Mansfield, no dip occurs, so that, as shown on Plate I, the Cretaceous beds may be found in this, what we term the *Sabine uplift* over a large area, buried not over 700 feet beneath Tertiary deposits. Minor uplifts, due probably not mainly to great crustal movements like that just described, but to concretionary growths of salt and gypsum, are to be seen to the east and west of the Sabine uplift. For an elaborate account of such minor, or salt and gypsum uplifts or domes, see Bulletin No. 7 of this Survey. Reference should also be made to that Bulletin if a knowledge of the areal distribution of the various Eocene stages is desired. In southern Louisiana and southeastern Texas local dome structure has served to collect enormous quantities of oil, as at Beaumont, Sour Lake and Jennings. In northern Louisiana, such structures are known to furnish some gas and oil, but scarcely in paying qualities. It is the great Sabine uplift that affords the proper structure for the collection and retention of great quantities of oil and gas in northwest Louisiana. The boundary of this uplift to the north, in the vicinity of Vivian, as shown by Plate II, A, is clearly defined. Likewise to the south, from near Natchitoches to the Sabine. So, too, there is apparently a high dip to the east, in the Cretaceous beds along the course of Red River. But to the west we have no sure proof that the Sabine uplift (indicated by interrupted lines on Plate I) may not be continuous with the interrupted line area further west in Texas. In other words, the insular mass, represented as the Sabine uplift on Plate I, might perhaps be more properly shown in the form of a peninsula connecting with the main land toward the west. A few wells, however, scattered from Shreveport to Dallas will soon determine this point and hence prove or disprove the existence of oil-collecting structure in this part of east Texas. The existence of a depression in the underlying rocks, or, in other words, of synclinal structure between Shreveport and Corsicana, whereby the Cretaceous may be more than 700 feet beneath the surface, we have inferred from the extensive display of Claiborne Eocene deposits in Rusk, Cherokee, and Anderson counties. Note that in Plate II, A, the Sabine Eocene is the surface rock over most of the Sabine up-

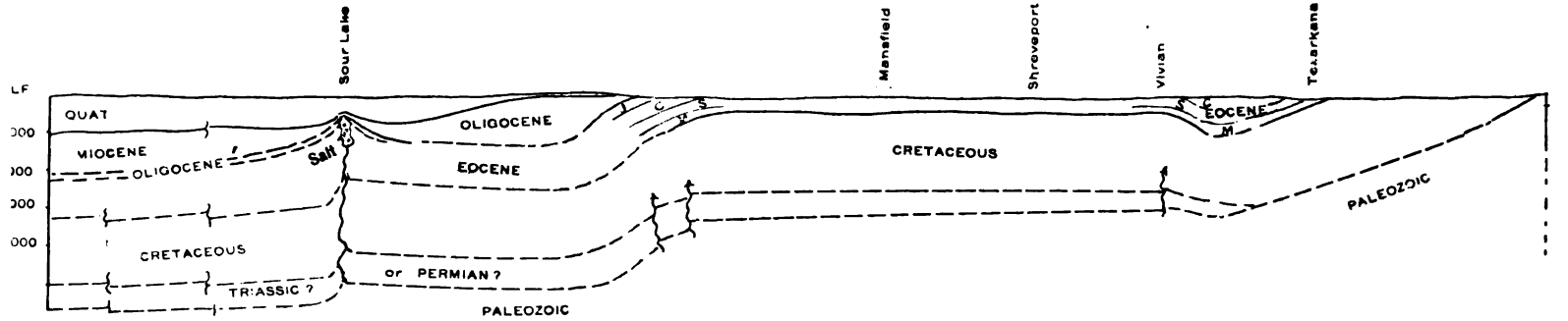

PLATE II. A—Generalized section from the Paleozoic outcrop in Arkansas, through Texarkana, the Sabine Uplift, Sour Lake, to the Gulf of Mexico near Galveston. The letters J, C, S, and M refer to the Jackson, Claiborne, Sabine and Midway stages of the Eocene series. Notice particularly the deep trough north of Vivian and the steep south dip south of "Mansfield."

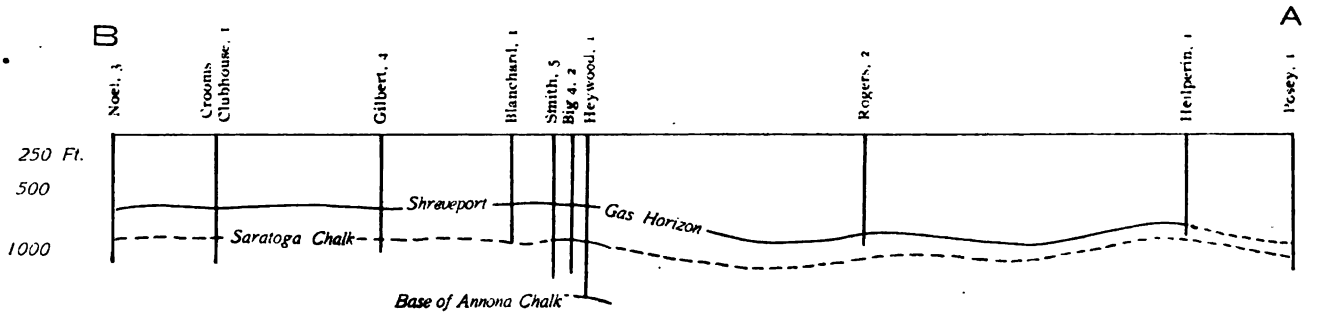

PLATE II. B—Section in the Caddo Oil Field along the heavy dotted line A-B on PLATE III. Notice the very slight undulations in the various beds.

lift. Claiborne Eocene occurs only in depressions and about the periphery of the uplift as shown by Plate II, A.

So far as we can now judge there is no reason why the border regions of the whole Sabine uplift may not be looked upon hopefully as oil and gas territory. We are naturally quite aware that the proper structure for gathering and retaining oil and gas may be present where there has never been a supply of these substances. It is one thing to have a system of pipelines and tanks for properly collecting and storing oil, and often quite another to have these receptacles full of oil. Until the origin of these substances is better understood, no one can tell with any degree of certainty where they may occur. But, given a certain amount of them in the underlying rocks of a region, structure plays a very important role in determining where they will collect in paying quantities. Caddo field is near the north angle of the Sabine uplift. Its oil and gas evidently come up the north and east slopes of this uplift and then become entrapped beneath Upper Cretaceous and Eocene impervious beds. But the final distribution of these substances over the field is seemingly due to secondary structuaral features, slight anticlines and difference of porosity of the rocks in which the oil is contained. We have suspected that the two directions of the shore lines of Ferry Lake and other topographic features have something in common with the structure in the underlying rocks. Mr. Perrine, who has assisted us in this investigation, has indicated, tentatively, the position of certain anticlines and synclines from data collected in the field from well logs, during November and December, 1908. These slight anticlines are seen in section in Plate II, B. They are certainly slight, but mean a great deal so far as production of oil and gas are concerned. The section is drawn along the heavy dotted line A-B, on Plate III.

KNOWN GEOGRAPHICAL LIMITS OF PAYING PRODUCTION.

So far as oil is concerned, the map, Plate III, herewith given, covers all the known producing territory of the Caddo field. The Posey well No. 1, one mile northeast of Vivian, was dry; but others along the anticline to the south as indicated on the map are small producers of heavy oil. Passing south along the

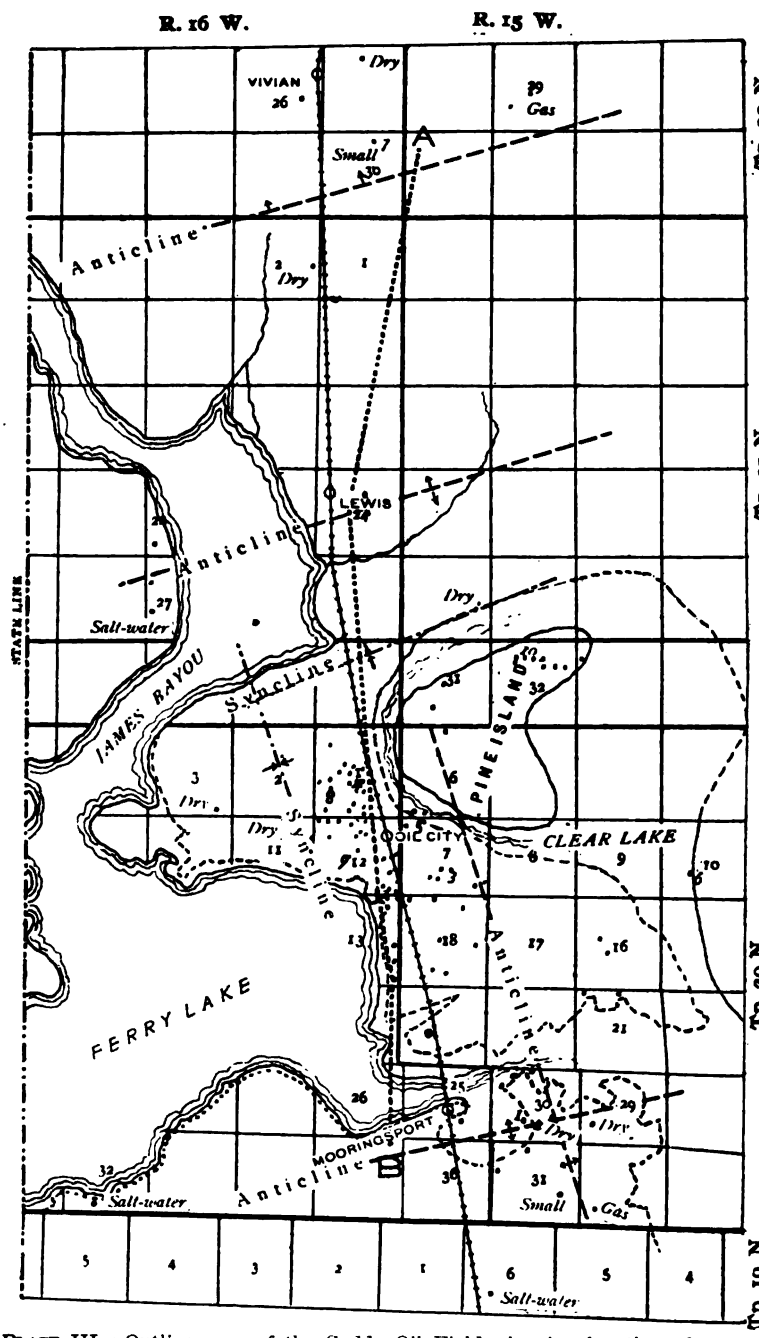

PLATE III. · Outline map of the Caddo Oil Field, showing location of section A-B (Pl. II, B), most probable location of slight anticlines and synclines, areas of greatest present development (wells shown by dots), location of limiting Dry or Salt-water wells, location of wells (numbered in italics from 1 to 10) from which samples were obtained for analysis. (See analyses, page 26.)

Vivian region: Little oil, heavy; much gas. Nacatoch horizon.

Lewis region: Little oil, heavy; much gas. Nacatoch horizon.

Pine Island: Gas from the Nacatoch sands; heavy oil and gas from the Woodbine.

Oil City, Sections 1 and 12: Gas from the Nacatoch, Austin and Woodbine; light oil from the Austin, locally; heavy oil from the Woodbine.

Oil City, south of, Sections 13 and 18: Gas in the Nacatoch and Woodbine; light and heavy oil in the Woodbine.

Mooringsport: Gas in the Nacatoch and Woodbine; light oil in the

Kansas City Southern railway beyond the "dry" territory in Sect. 2, to the vicinity of Lewis, a few small producers are met with from the same sand that occurs in the Vivian wells. Across James bayou, in Sections 22 and 27, the same horizon is being exploited. Small wells of heavy oil, with gas and salt water, are there met with. From Pine Island to Mooringsport the territory is generally productive. So far, however, there is little to encourage "wildcatting" over a mile west of the range line between RR. 15 and 16 west. Sections 2, 3 and 11, north of Ferry (Caddo) Lake and section 32 to the south have proven unproductive; likewise wells near and to the south of the line between Tps. 19 and 20 N. Little oil has been found over a mile east of Mooringsport. But four miles east of Oil City, in section 10, there is a good well, producing from 100 to 400 barrels daily. Section 18, one mile southeast of Oil City, seems not only to be the central part of the largest developed area, but it also yields oil, in many instances of superior quality.

GEOLOGIC HORIZONS OF OIL AND GAS.

Gas and oil occur separately or together in at least four horizons in the Caddo field. However, as already remarked, they are all in the Cretaceous system. They occur in the Nacatoch, Austin, Eagle Ford and Woodbine stages, as indicated in the following table:

Generalized Section of the Caddo Field

SYSTEM	SERIES	STAGE	KIND OF MATERIAL	Approx Thick'ss Feet	Approx Depth Feet
Quaternary			Red and gray sand, clay; gravel	20	20
Tertiary	Eocene	Sabine	Dark lignitic sands and clays, with calcareous boulders.	430	450
		Midway	Dark clay, with occasionally a lime stone bed.	200	650
Cretaceous (Upper)	Montana	Arkadelphia	Dark stiff clay.	150	800
		Nacatoch	"Shreveport" or "Caddo" gas sand; contains some hard layers.	130	930
	Colorado	Marlbrook	Blue marl with chalky layers about 1150 ft. (Saratoga chalk)	350	1280
		Austin	Chalky layers with many fossil fragments, often with strong odor of oil. Occasionally good OIL about 1575 ft. Gas common. The so-called Annona chalk.	320	1600
			Clay, chalk and sand, with hard pyrite layers. The Brownstown beds.	200	1800
		Eagle Ford	Blossom sands. Gas at 1800 ft.	50	1850
			Blue tough clays with hard limestone and pyrite layers. The "Eagle Ford clays."	350	2200
	Dakota	Woodbine	These sand beds are reached at depths ranging from 2140 to 2300, according to local structural features. They contain the "deep" OIL and GAS of the Caddo fields. Salt water common, thickness unknown, (100 ft.)		

The Nacatoch Stage.—This stage furnishes practically all the gas now being used. It is generally dry, but sometimes it is accompanied by salt water. About 800 feet may be taken as the average depth of this sand in the Caddo field, in its restricted sense, though variations of 50 feet more or less must be expected owing to topographical and structural features. The inference must not be made that until a depth of 800 feet

is reached there are no gas "showings." These are often very noticeable between 600 and 800 feet. At Lewis and to the west of James bayou this sand is a little over 1,000 feet down; and in the Trees wells, in the last-mentioned locality, considerable heavy oil and salt water (300 barrels daily of each, in one instance,) came from this horizon. Again, near Vivian, in section 36-22-16, three wells in this "shallow sand" are reported good for 150 barrels of oil, with about eight times that amount of water. Three miles east, the Busch-Everett people estimate an 8″ hole 1,036 feet deep (Sect. 29-22-15) capable of furnishing 75,000,000 cubic feet of gas daily.

We have little hesitation in stating our belief that this is the horizon furnishing the "heavy oil" in the Powell field just east of Corsicana, Texas.

The thick, stiff Arkadelphia clay beds above, furnish an excellent capping for the hydro-carbons collecting in this bed. The porous sands, over 100 feet thick, allow of easy movement of the gas between the sand grains. But in some instances the capacity for holding gas is seemingly increased by the cavities in the silicious rock layers left after the calcareous marine shells have been dissolved out. It is unnecessary usually to go but two or three feet into the sand to obtain an enormous supply of gas. This method of procedure lessens the danger from salt water. Certain Vivian logs, however, record penetrating the gas sand for 15 or 16 feet. The top of the sand is nearly 400 feet above the Austin chalk. From about this horizon the oil and gas in the Corsicana field are found. See statements in the generalized section in Texas given below:

Generalized Section of the Austin Quadrangle

SYSTEM	SERIES	STAGE	KIND OF MATERIAL	Approx Thickn's Feet
Quarternary			Silt, sand and gravel.	40
Tertiary	Neocene	Uvalde	Gravel.	50
	Eocene	Lytton	Clay, sand and sandstone.	300
Cretaceous (Upper)	Montana	Webberville*	Black, slaty, bituminous clays with occasional harder layers. Distinguished from the Taylor marl by its glauconitic particles.	400
	Colorado	Taylor	Blue unctuous marly clay ("joint clay"), weathering into yellowish subsoil and black soil.	540
		Austin	White chalk with conchoidal fracture. Marly in upper portion.	410
		Eagle Ford†	Blue clay and flaggy limestone.	30
Cretaceous (Lower)			(These beds have not been reached in the Caddo field.)	

* Slight amounts of oil and gas are reported by Hill and Vaughan from the Webberville beds about Austin. The Corsicana oil is, according to these authors, from the Webberville beds.

† About Austin the Eagle Ford clays contain a slight amount of oil. (See Austin folio, U. S. G. S. No. 76, p. 7.)

Whether the light Corsicana oil from the town of Corsicana, Texas, comes from the Nacatoch, or the equivalent *Webberville beds*, as stated by Hill and Vaughan, or whether they form the Texas representative of the Marlbrook, *i. e.*, the *Taylor beds*, as stated by Adams, we cannot now say positively. However, we are inclined to believe Adams' view is the correct one; also, that conditions in Marlbrook days may have been locally more or less like those obtaining earlier in Austin times. We shall see below that the Annona beds of the Austin stage sometimes furnish a large quantity of high-grade oil.

Corsicana field.—Apropos of looking for other oil horizons in beds penetrated in and about the Caddo field, a few facts are

given from the Corsicana field. The old Corsicana field was formerly described as one mile wide east and west and four miles long north and south. The rocks dip 50 feet to the mile, south, 70° east. Depth of the producing sand varies from 950 feet in the north to 1,175 in the south. Toward the east the sands are filled with salt water, toward the west they pinch out or contain very little oil. They are capped by impervious "Ponderosa marl." In the Powell or heavy oil field the dip is still easterly and the wells may strike productive sands from 700 to 800 feet down. Clearly the Powell oil is from a somewhat higher horizon than the light, Corsicana oil. It is also interesting to note how the production has varied and held out in the Corsicana and nearby Powell fields. In the former, wells that were furnishing from 10 to 30 barrels daily when first put down in 1897 were furnishing about half that amount in 1902, or five years afterward. These two Texas fields produce approximately 500,000 barrels annually. But in 1900 the Corsicana field alone ran as high as 800,000 barrels. In 1907 about the same amount was again produced by the combined fields, but about 600,000 barrels came from the heavy-oil, Powell field.

Analysis of Corsicana Oil.—The Corsicana product has been analyzed on several occasions. Dr. Thiele's analysis, as quoted several times in the "Mineral Statistics of the United States Geological Survey," is as follows:

	Per ct.	Sp. Gr.
Naphtha	10.8	0.710
Kerosene (illuminating product mainly)	54.5	0.796
Residue	34.7	0.906

More elaborate analyses may be found in Mineral Statistics for 1901 and 1902.

We strongly suspect that the Lea development reported from seven miles north of Corsicana, where 7 barrel wells of 42° B oil, are found in a "sand" 725 feet deep, are in the lower beds of the Marlbrook or perhaps even in the Austin chalk.

The Austin Stage.—At about the central part of this stage (or near the base of the so-called Annona chalk), gas and strong

petroleum odors are generally met with. But sometimes, as in the C. G. No. 1 on the Caddo Lake Oil and Pipe Line Company lease, SW, SW, 1-20-16, it yields a large amount of excellent oil. In this case it is clear, from comparative depths to various strata in surrounding wells that were failures, that the well is located on a slight dome; moreover, the limestone seems to be very porous. This well was credited with a flow of 3,000 barrels at first, though it soon dropped to 1,000; gravity, as reported in the Oil Investors' Journal, is 42° B. The first well in the field, the old Savage and Morrical well No. 1, yielded a barrel or so a day of 34.7 B. oil from this horizon. Even as far east as Pine Island, this oil-bearing stratum has been noted. It there was reported to have a depth of 1,640 feet.

The Annona chalk furnishes an excellent means for determining structure in this part of the State, since it varies so markedly in appearance from the usual dark clays and sands. The "cuttings" are white and appear like fragments of plaster scattered about over old well dumps. During the process of drilling, this chalk renders the return water as white as milk. The presence of Annona beds in the Caddo field, ranging in depth from 1,270 to 1,600 feet in depth; the occurrence of the same beds at about the same depths in the Blocker well ten miles southeast of Marshall, Texas, also at the same depths in the Shreveport wells; while in the well five miles northwest of Plaindealing they are first met with at a depth of not less than 1,750 and perhaps 2,300 feet, according to different logs of the same, all show clearly the plateau-like character of the structure we have styled the Sabine uplift.

The Eagle Ford Stage.—This stage is said to show slight oil signs in the Austin, Texas, region. At Clarksville it furnishes in its upper member, the Blossom sands, a good supply of soft water. In the Caddo field, this upper sandy member is of variable thickness and often shows excellent signs of oil and gas. Salt water is prevalent in this horizon, but doubtless the gas may be utilized after the depletion of the shallower horizon. In the lower Eagle Ford Clays, pyrite nodules and layers are common, and drilling in them is sometimes very slow and expensive. These layers, embedded in tough clays,

aggregate over 300 feet in thickness and form an excellent capping for the gas and oil in the Woodbine sands below.

The Woodbine Stage.—The "sand" of this stage furnishes nearly all the oil in the Caddo field. In the central part of the field it may be looked for between 2,225 and 2,265 feet, while on Pine Island it is perhaps generally about 100 feet less in depth. That there is in the center of the fields as now developed no simple sand bed from which all wells derive their supply of oil is clear from the somewhat varying depths of best supply and the difference in the gravity of the oil. The Gilbert No. 1, for example, is probably deriving its oil from a depth of about 2,245 feet; its gravity is 39° B. The Filer well, scarcely a mile east, at about the same depth produces oil with a gravity of 22° B. Some wells in section 12 are credited with a producing depth of 2,300 feet. In one instance a strainer 40 feet long extended from 2,225 to 2,265 feet in the wells, showed little oil at first, but in a few hours produced a large quantity of excellent oil from an unknown depth. A Busch-Everett well in section 30, just west of Dixie, showed a little oil at 2,330 feet.

Oil Production of the Caddo Field.

The following figures, taken from the Oil Investors' Journal, will give a good idea as to the amount of oil produced thus far in the Caddo field:

1905	Bbls.
1906	4,650 (1,510 shipped)
1907	48,266
1908	513,504

At semi-monthly intervals, the same authority furnishes the following estimates of daily production for the last twelve months:

May 15, '08, 1,450 bbls.; May 31, 2,010; June 15, 2,200; June 30, 2,285; July 15, 2,000; July 31, 1,700; Aug. 15, 2,000; Sept. 15, 2,000; Sept. 30, 4,500; Oct. 15, 2,700; Oct. 31, 3,600; Nov. 15, 3,100; Nov. 30, 1,900; Dec. 15, 3,750; Dec. 31, 3,000; Jan. 15, '09, 3,275; Jan. 31, 2,700; Feb. 15, 2100; Feb. 28, 2,580; March 15, 3,000; March 31, 2,850; April 15, 3,100; April 30, 2,930; May 15, 2,650; May 31, 3,100.

It is quite probable that the production of the field for 1909 will be about 1,000,000 barrels. This means that in oil alone it will surpass the maximum output of the combined Corsicana-Powell fields.

Concerning the importance of the Caddo oil field and the mode of occurrence of the oil, we still hold the same opinion we expressed in the Oil Investors' Journal, Nov. 6, '08:

> It is a most important fact to note that this field is not one of extreme local concentration. It has nothing in common with the Beaumont or Jennings fields, but everything, save age, in common with those of western Pennsylvania, West Virginia, Ohio and Illinois. Its vastness speaks well for both quantity of oil and gas and the longevity of the field.

The comparative slowness in development of the Caddo field has frequently been commented upon. This slowness has been due to the fact that the earlier, shallower wells were troubled with heavy gas pressure and furnished little oil. The first really successful deep wells furnished heavy oil. Richardson No. 2, on the Etcheson and Mayfield land, section 32-21-15, was a fine producer at the start, being rated as 300 barrels per hour. It went to mud and water in a day or two and sanded up. September 6, '08, the C. G. O., on the Gilbert tract, came in with a daily production of 400 barrels of light oil (see table of analyses). Producers' Nos. 1 and 2, on the Lane tract (section 18-20-15) were also soon brought in, showing high-grade oil and larger quantities than furnished by the Gilbert well. The same high-grade oil was known to exist in the Hostetter well, east of Mooringsport, for over a year before the exciting days when the Guffey-Hostetter No. 2 was completed. The latter event took place in December, '08, and rumor had it that a 10,000-barrel well had been brought in. Shipments from Mooringsport, however, soon showed that the new well was making about 300 barrels daily.

Upon the whole, Producers' No. 2, on the Lane tract, as noted above, has been the best well in the field so far. It commenced flowing in September, 1908, at a reported rate of 1,000 barrels daily and as late as March, '09, was still flowing 500 barrels daily.

Good quantities of high-grade oil (see analysis of Gilbert No. 1, p. 20), have been produced, therefore, from the "deep

sand" (Woodbine), in sections 13 and 18, about a mile south of Oil City and in section 30, east of Mooringsport. Other localities furnish from this horizon a heavy oil, often with much salt water.

Local, porous lenses in the Austin chalk, as already mentioned, in section 1, three-quarters of a mile northwest of Oil City, also furnish a fair supply of high-grade oil.

Small quantities of heavy oil are found in the Nacatoch sand—west of James Bayou, sections 27 and 22—three wells furnishing 85 barrels daily; the Rogers well, at Lewis, 30 barrels; the Vivian Oil Company three wells, in section 36, near Vivian, 150 barrels.

Shipping Facilities.

Until the present summer ('09) practically all shipments had to be made by the Kansas City Southern railway. Loading racks were established at Caddo, Oil City, and Mooringsport. Now, a 6" pipe has been constructed from the Caddo field to Grigsby's Island, just south of Shreveport. This will permit of railway shipments over at least a half dozen roads, as well as water transportation on the Red River. Doubtless, too, the connection of the field with the Standard's pipe line from Oklahoma to Baton Rouge is a matter of the near future.

Analyses of Caddo Oil.

In collecting samples for analyses it was our intention to get representative samples from all oil-producing horizons and from localities as widely separated as possible. Note: Sample No. 7 is from the "shallow sand" (Nacatoch) horizon; No. 4 is from the Annona chalk; Nos. 1 and 2 are from the deep sand light oil beds; others are "deep sand" (Woodbine) heavy oil beds. Again, sample 1 is from Mooringsport; 7 is from Vivian; 8 is from the western part of the field; 10 is from Pine Island, and 6 is from across Black Bayou. The analyses, though not complete, certainly give a very fair impression of the character of the oil being now obtained from the Caddo field. The location of the wells may be seen by consulting Plate III. The figures in italics indicate the well from which samples were taken.

Salt water and gross impurities are separated from the oil

by boiling in huge tanks, near the bottom of which a series of steam pipes are located (see Plate IV, A).

PLATE IV. A—"Boiling tank" for the elimination of mud and salt water from the oil.

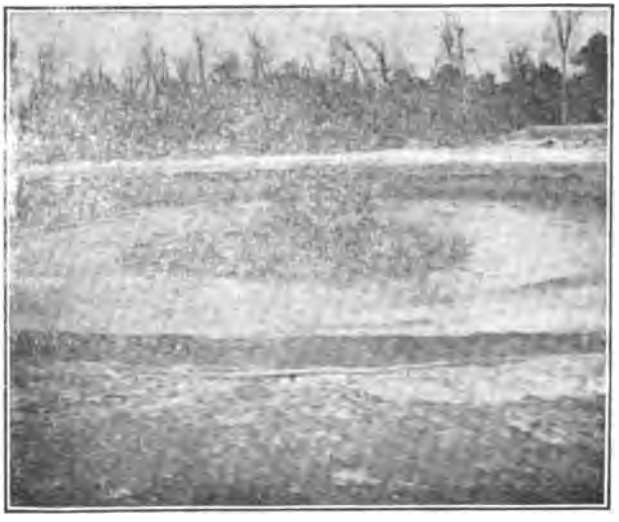

PLATE IV. B—Caddo Gas and Oil well, Gilbert tract, old No. 1, "running wild." Probably 25,000,000 cubic feet of gas has escaped here daily for over three years. The gas caused the thick, heavy red, muddy water to have the appearance of boiling violently. (See page 21.)

Number of Specimen	LOCATION OF WELL	Number of Well	Depth of Well	Physical Properties Gravity 60° F. Specific	Baumé	Distillation Engler's Method Begins to Distill at	By Volume To 150° C. Cubic Centimeters	150°-300° C. Cubic cent.	Specific Gravity	REMARKS	Geological Horizon by G. D. Harris
1	Hostetter Farm, Mooringsport.	1	2210	0.8187	41	138	3	55	0.7778		Woodbine
2	Caddo Oil, Gilbert No. 1 N. E., N. E. S. 13-20-16	1	2245	0.8264	39 4	136	115	49	0.7778		"
3	Frank Filer, N. W., S.E., S 7-20-15	1	2240	0.9211	22 0	200		12	0.8510	Contains Water	"
4	Old Caddo Gas and Oil Co. Oppenhauser tract	1	1620	0.872	30 5	210		28	0.8299	"	Austin
5	Richardson well NW, NW, Sect. 7-20-15	2	2245	0.8929	26 8	173		20	0.8408	"	Woodbine
6	Black Bayou Oil Co. SW, Sect. 10-20-15	1	2220	0.9150	23 0	210		18	0.8450	"	"
7	Dawes well, (1 mile East of Vivian) NW, NE, Sect. 36-22-15	1	1050	0.9253	21 3	265		17	0.8406	"	Nacatoch
8	Caddo Gas and Oil Co. E. K. Smith tract	4	2260	0.9211	22 0	200		14	0.8142	20% H2O; 0.7% clay	Woodbine
9	Producers-Caddo Oil and Min. Co. NE, NW, 12 20-16	6		0.8889	27 5	220		18	0.8406	Much Water	"
10	Richardson Oil Co. NE, NW, Sect. 32-21-15, Pine Island	4	2152	0.9121	23 5	220		16 5	0.8713	"	"

NOTE: All the above specimens were black in color, except No. 8, which was brown. The odor of the above specimens is like that of Oklahoma oil. No sulphur was found present in any of the samples. U. S. Geol. Survey.

GAS IN THE CADDO FIELD.

Gas, in immense quantities, seems to have a more general distribution than oil in the Caddo field. For years gas has been known from the Nacatoch sands beneath Shreveport. Its real significance, however, has been appreciated only of late. From Mooringsport north to Vivian and from west of James Bayou east to Dixie, gas has been found in enormous quantities. This field first attracted the attention of the general public by its famous burning gas wells or so-called "burning geysers." Producers' No. 2 "blew out" in May, 1905, with terrific force. The gas caused the waters in and about the well to present a boiling, churning motion, that loosened up the earth some yards around the well, engulfing the derrick and machinery in a mass of liquid earth. On June 18 the gas was lit and thereafter for five months this geyser attracted visitors from all parts of the country. Major Frank M. Kerr visited the well in behalf of the State to see what might be done to stop the waste of gas; and, in his report to the Governor, says in part:

> On the day of this visit the well presented a scene of magnificent energy and surprising spectacular effect. A basin or bowl of water some 250 feet in diameter has resulted from the action of the escaping gas, and the roll of the waves from the mouth of the orifice toward the rim of the basin is like waves on a sea beach in stormy weather, from the centre of which leaps a flame some 30 feet in diameter and equally high. This, with the monster upheaval of water and leaping of spray, presents a spectacle which might readily have been likened to the display of a prismatic fountain of unusual magnitude and superb effect.

Producers' No. 3, in the same vicinity, *i. e.*, a few hundred yards west of Oil City, repeated the history of No. 2 in a somewhat milder form during the latter part of 1906 and early part of 1907.

Caddo Gas and Oil Company's well No. 1, on the Gilbert tract in the eastern part of section 13, perhaps 200 yards west of the railroad and about one and a quarter mile south of Caddo City, has had a remarkable history as a "geyser" or "wild well." After a period of over three years of constant eruption it still appears vigorous, as shown by the accompanying figure (A, Plate IV). The description of Producers' No. 2, given above, with but slight modification of details, fits this well excellently. When lighted, the heat of the flames raises the

water to the boiling point; the tumbling and seething of the waters and the roar of the escaping gas and the light and heat of the leaping flames produce an impression long to be remembered. The details of the boiling, red, muddy waters appear more clearly when the well is not on fire, as shown by the figure. The "crater" is about 300 feet in diameter. The greatly disturbed central part of the circular body of water is over 30 feet in diameter. When lighted the flames are from 20 to 60 feet high.

Another famous "burning well' was that known as Dawes Trustee No. 1, NE. NW, Section 7-20-15. A brief history of this well is given under "Alphabetical List of Wells in the Caddo Field." This well alone probably wasted 40,000,000 cubic feet of gas daily between the middle of May, '08, and February 12, '09.

During the latter part of 1908 we estimated the daily waste of gas in this field to be about 70,000,000 cubic feet.

In June, 1908, the Oil Investors' Journal correspondent listed the producing gas wells of the Caddo field as follows:

Producers' Oil Co., Heilperin and Liebman, Sec. 6, 2,200 ft., 2½" hole, 8 million gasser, rock pressure 900 lbs.

McGuire No. 1, Barron, Sec. 17, 802 ft., 20 million.

McGuire and Evans No. 2, Sec. 18, 812 ft., 15 million.

McGuire and Evans No. 3, Sec. 18, 2,000 ft., north of No. 2, 15 million.

McGuire No. 4, Barnhardt, Sec. 21, 812 ft., 15 million.

McGuire No. 5, Huckaby, Sec. 17, 823 ft., 25 million.

McGuire No. 6, Walter Crawford, Sec. 15, 1,500 ft. north of McGuire No. 4, 15 million.

McGuire No. 7, Barnhardt, Sec. 21, half mile east of McGuire No. 4, 795 ft., 15 million.

J. B. & W. S. Atkins, NE. NW, Sec. 18, Evans, 15 million.

J. M. Guffey Petroleum Co., Hostetter No. 1, 810 ft., 15 million.

Dixie Oil and Pipe Line Co. No. 2, southeast part of Pine Island, 800 feet, small gasser.

The following gas wells have been announced in this journal since June, 1907:

McGuire No. 9, school land, Sec. 16, 805 ft., 20 million.

Cullinan and Jolly, No. 1, 810 ft., 25 million.

McGuire No. 10, school land, Sec. 16, 825 ft., 20 million.

Dixie No. 2, Glassel, 5½ miles east of Mooringsport, Sec. 36.

McGuire No. 11, school land, 25 million.
Caddo Gas and Oil, Pardue, Vivian, 2½ million.
Caddo Gas and Oil No. 9, Mooringsport, 8 million.
Caddo Gas and Oil No. 10, Mooringsport, 10 million.
Caddo Gas and Oil No. 11, Smith, 15 million.
Producers' No. 2, Murray, NW, SW, Secs. 7-20-15.

McCann & Harper No. 1, Pitts, NE, NW, Secs. 31-22-15, Vivian, 50 million.

Busch-Everett No. 1, Douglass, SW of Secs. 30-20-14, Dixie, 10 million. Dry at 2,330 feet.

Busch-Everett No. 1, Vivian Mercantile Co., Secs. 29-22-15, 60 million, 8″ hole, depth 1,040 feet.

Utilization of Caddo Gas.—The amount of gas escaping naturally at the surface near the old Savage and Morrical well was formerly collected and used for fuel and light in a frontiersman's cabin.

Producers' No. 1, a few hundred yards northwest of Oil City, now blowing salt water and gas, was the first well to furnish a large amount of gas for drilling purposes in the field. The Citizens' Oil and Pipe Line Company, with a capitalization of $3,000,000 put down the first gas pipe-line (6-inch) to Shreveport in the fall of 1905 and early part of 1906. Gas was first distributed May 20, '06. For domestic purposes the price charged was 35c per 1,000 cubic feet, for manufacturing and general power purposes 17.5c. A second pipe line was laid in 1907, and in the latter part of 1908 an 8″ line was carried north from Lewis to Texarkana. Dixie began to use natural gas from the wells nearby in the fall of 1908, and a line was carried northward to Belcher.

By far the greatest undertaking relative to the utilization of natural gas from the Caddo field is that of the Busch-Everett people of St. Louis, who have received a franchise to furnish New Orleans with this fuel. To successfully lay a 16, 20 or 24-inch pipe a distance of 400 miles, crossing bayous, swamps and even the Atchafalaya and the Mississippi rivers, is certainly considerable of an undertaking, involving doubtless an expenditure of $10,000,000. Prices for gas in New Orleans will vary from 35 to 45 cents per thousand cubic feet in accordance with the amount used. The line is to be operated in two and one-half years.

St. Louis has been mentioned as a possible market for Caddo gas.

Analysis of Caddo Gas.—The analysis and remarks of Prof. C. F. Phillips, already frequently quoted in scientific journals, are as follows:

Analysis of Caddo Gas.

Methane	95.00
Nitrogen	2.56
Carbon dioxide	2.34
Hydrogen	.00
Carbon monoxide	.00
Ethylene	.00
Sulphide (Sulph. hyd.?)	.01

"I think you have a valuable fuel in this gas, well suited for household heating or metallurgical purposes and for all purposes to which natural gas is applied."

LOGS OF REPRESENTATIVE WELLS IN THE CADDO FIELD.

Log of Filer No. 1.

(Record received from Mr. Plumb.)

	Thickness Feet	Depth Feet		Thickness Feet	Depth Feet
Clay	75	75	Shale	50	1,040
Sand	5	80	Gumbo	29	1,069
Dark Clay	20	100	Gumbo	51	1,120
Rock	4	104	Shale	80	1,200
Clay	11	115	Lime, soft	100	1,300
Rock	3	118	Lime, hard	140	1,440
Shale	57	175	Rock	10	1,450
Rock	2	177	Lime, soft	80	1,530
Shale	148	325	Rock	10	1,540
Rock	3	328	Lime, soft	25	1,565
Shale	172	500	Shale	115	1,680
Rock	4	504	Gumbo	80	1,760
Gumbo	121	625	Shale, hard	115	1,875
Rock	5	630	Rock	5	1,880
Gumbo	50	680	Shale	110	1,990
Shale, hard	20	700	Rock	8	1,998
Shale, soft — some gas	20	720	Shale	52	2,050
			Rock	10	2,060

	Tickness Feet	Depth Feet
Shale and gumbo..	90	810
Rock..	80	890
Shale, hard.....	60	950
Gumbo	40	990
Shale.....	75	2,135
Rock....	5	2,140
Shale	100	2,240
Good oil sand.....	12	2,252

Log of Gulf Refining Company Hostetter No. 1.

(Record received from B. G. Dawes.)

	Thickness Feet	Depth Feet
Clay and shale.....	29	29
Hard dark sand rock	2	31
Light gumbo and shale....	74	105
Dark lime rock.....	3	108
Light gumbo.....	15	123
Sand, rock and shell	1	124
Blue shale.....176		300
Sand rock, shells and shale*.....	10	310
Blue shale and light gumbo 338		648
Brown shale—much gas	27	675
Shale and gumbo ..131		806
Soft sand rock—gas	2	808
Brown sandy shale.	7	815
Hard brown shale..	5	820
Top of Caddo gas sand at.....		820
Gas sand.....	8	828
Hard brown shale..	32	860
Sand rock with gas.	2	862
Hard brown shale, soft at base.....	38	900
Light gumbo mixed with white shale..258		1,158
Hard white lime rock and broken shale 210		1,530
Light gumbo mixed with kaolin and white shale.....115		1,645
Brown shale mixed with pyrite.....	2	1,647
Brown shale.....	14	1,661
Brown shale and pyrite	3	1,664
Gumbo turning to shale	59	1,723
Hard brown shale..	19	1,742
Coarse brown packed sand.....	8	1,750
Light brittle gumbo	30	1,780
Coarse brown packed sand.....	6	1,786
Light gumbo and blue shale.....	44	1,830
Coarse brown packed sand, almost sandstone	10	1,840
Stiff blue shale.....	68	1,908
Brown packed sand.	7	1,915
Blue shale turning brown	89	2,004

*(Well bailed here, showing a capacity of about 2,500,000 cubic feet of gas per day, but salt water flooded the hole at once.)

	Thickness Feet	Depth Feet
Light lime rock	13	1,173
Gumbo and blue shale	148	1,320
Stiff blue shale	96	2,100
Light brown shale	105	2,205
Light colored gritty sandstone with gas and oil	4	2,209

Log of McCormick's Shreveport Brickyard Well.

(Log received from W. McCormick.)

	Thickness Feet	Depth Feet
Gray clay	20	20
Lignite	4	24
Gray shale	60	84
Shale	16	100
Shale and pipe clay	80	180
Gray shale	120	300
Brown shale	100	400
Dark shale	200	600
Shale and rock	200	800
Gumbo (pyrite in the last few feet)	150	960
Rock	2	962
Shale	138	1,100
White rock with shale mixed	500	1,600
Clay and gumbo	200	1,800
Sand rock at		1,800
Rock and shale	100	1,900
Gumbo and shale	100	2,000

Log of B. G. Dawes and Gulf Refining Company Posey No. 1, Vivian, La.

(Record received from B. G. Dawes.)

	Thickness Feet	Depth Feet
Clay and yellow sand	197	197
Blue sand	53	250
Shale	8	258
Rock	3	261
Water sand, blue and yellow	209	470
Lime rock	1	471
Rock	18	489
Sand	9	498
Boulders	40	538
Boulders, with soft places between	12	550
Gumbo	1	1,006
Rock	1	1,007
Blue shale, with hard streaks	11	1,018
Boulders	2	1,020
Shale	5	1,025
Boulders	2	1,027
Blue shale	4	1,031
Hard rock	1	1,032
Dark gumbo	12	1,044
Rock	2	1,046
Gumbo	8	1,054
Blue shale	48	1,102

	Tickness Feet	Depth Feet
Rock	5	555
Rocks, with soft places between	4	559
Rock	6	565
Rock and sands	35	600
Rock with soft streaks	75	675
Gumbo	21	696
Soft rock and sand	1	697
Gumbo	29	726
Gumbo	141	867
Boulders	1	868
Gumbo	15	883
Boulders	2	885
Gumbo	14	898
Boulder	1	899
Black gumbo	13	912
Black shale	20	932
Shale	64	996
Rock, with gas	2	998
Rock with pyrite	7	1,005
Gumbo	6	1,108
Gray rock with sand	5	1,113
Bastard shale	11	1,124
Gray rock with sand	1	1,125
Dark shale	10	1,135
Gray rock	1	1,136
Blue shale	29	1,165
Rock sand	6	1,171
Blue shale	6	1,177
Rock with soft streaks	48	1,225
Shale	63	1,287
Gray rock with sand	2	1,289
White shale	40	1,329
Sand rock	5	1,334
Blue shale	22	1,356
Gray rock, hard	4	1,360
Gumbo	37	1,397
Boulder	1	1,398
Tough blue gumbo	9	1,407

B. G. Dawes and Gulf Refining Company Heilperin No. 1, Vivian, La.

(Record received from B. G. Dawes.)

	Thickness Feet	Depth Feet
Surface clay	7	7
White sand	21	28
Quick sand	12	40
Gray sand	10	50
Water gravel	6	56
Dark gumbo	5	61
Dark water sand	24	85
Hard packed sand	17	102
Water sand	53	155
Hard rock	5	160
Blue sand	21	181
Gray hard rock	4	336
Blue shale	6	342
Gray rock	1	343
Bastard gumbo	12	355
Gray rock	1	356
Dark gumbo	20	376
Dark shale	24	400
Gumbo	14	414
Shale	10	424
Tough gumbo	277	701
Shale	6	707

	Tickness Feet	Depth Feet
Gray rock	2	183
Dark sand	4	187
Soft rock	1	188
Sand	4	192
Sandy rock	1	193
Blue sand	51	244
Rock	2	246
Rock, gray and hard	3	249
Blue sand	18	267
Bastard gumbo	13	280
Blue shale	18	298
Tough dark gumbo	13	311
Boulders	2	313
Dark shale	11	324
Black gumbo	8	332
Gumbo	131	838
Shale with oil	22	860
Tough gumbo	8	868
Blue shale	12	880
Dark gumbo	62	942
Gypsum, kaolin shale, or limestone show of oil	18	960
Blue gumbo	41	1,001
Sandy shale	9	1,010
Black gumbo	52	1,062
Rock	1	1,063
Rock with gas	4	1,067
Gas sand	30	1,097

Log of Heywood No. 1 Fee.

(Record received from H. H. Jones, driller.)

	Thickness Feet	Depth Feet
Clay, variegated, soft	80	80
Bluish sand, water bearing	10	90
Clay, dark, soft	50	140
Hard dark rock	2	142
Dark soft clay	8	150
Hard dark rock	3	153
Gumbo and shale, dark, full of boulders	447	600
Gumbo and dark shales	110	710
Shale, dark, with persistent gas	10	720
Gumbo, dark and very tough	100	820
soft	11	1,155
Dark gumbo	53	1,208
Dark shale	21	1,229
Dark gumbo	43	1,272
Chalk, clayey to white, oil from 1,470 to 1,520	328	1,600
Black rocky gumbo	100	1,700
Black sandy gumbo	80	1,780
Rock with some pyrite	5	1,785
Coarse, variegated sand, with oil smell	13	1,798
Rock in streaks sand and some pyrite	62	1,860
Gumbo and shale	112	1,972

	Tickness Feet	Depth Feet
Rough, limelike rock with gas	10	830
Dry sand rock, with gas and oil smell.	34	864
Rough lime rock...	5	869
Dry sand rock, with oil and gas	61	930
Hard rock	2	932
Sand rock	8	940
(Gas occurred in this well from 820 to 940 feet.)		
Shales, with streaks of gumbo	39	979
Rock	2	981
Shale and gumbo with hard streaks.	163	1,144
Chalk, white and tough gumbo	40	2,012
Shale and dark gumbo	118	2,130
Rocky, with pyrite and shells	13	2,143
Red and dark shale.	37	2,180
Blue shale	16	2,196
Rock	2	2,198
Soft rock	2	2,200
Hard shale	24	2,224
Oil shale	3	2,227
Hard shale	5	2,232
Oil shale	4	2,236
Hard shale	3	2,239
Rock	3	2,242
Brittle rock	10	2,252
Shale	5	2,257

Log of Blanchard No. 1 Graham.

(Record received from Mr. A. G. Curtis.)

	Thickness Feet	Depth Feet
Red and yellow clay	50	50
Water sand	25	75
Gray packed sand..	50	125
Gumbo and shell rock	30	155
Blue shale	29	184
Shale and iron concretions	26	210
Shale and iron concretions	30	240
Shale and gumbo...	81	321
Shale, rock and gumbo	80	401
Shell rock	29	430
Shell and gumbo...	47	477
Shale with streaks of shell rock	20	1,900
Shale	63	1,963
Hard sand rock....	5	1,968
Sand rock with Shells	90	2,058
Very sticky gumbo.	32	2,090
Blue shale	92	2,182
Shells of sand rock, with oil	11	2,193
Blue shale	87	2,280
Hard gumbo, shelly.	11	2,291
Hard rock	1	2,292
Blue shale and white clay, small shells.	12	2,304

	Thickness Feet	Depth Feet
Shale	98	575
Rock	4	579
Shell	10	589
Shell rock	89	678
Shale and gumbo	6	684
Shell rock at		684
Blue shale—first gas	16	700
Blue shale, with oil and gas	50	750
Blue shale	87	837
Rock	3	840
Tough gumbo	95	935
Shale and gumbo	95	1,030
Hard rock	8	1,038
Hard shale, with shell rock	31	1,069
Rock	106	1,175
Solid gumbo	155	1,330
White rock or shale	218	1,748
Gumbo	132	1,800
Shale, with small shells and salt water	11	2,315
Shale with hard streaks	26	2,341
Brown and blue shale	4	2,345
Sand rock	5	2,350
Red and blue shale	20	2,370
Sand rock	10	2,380
Red and blue shale	30	2,410
Shale	15	2,425
Very thin rock at		2,425
Red and blue shale	5	2,430
Sand rock breaks	10	2,440
Red and blue shale	16	2,456
Rock	2	2,458
Blue shale	16	2,474
Rock sand	2	2,476
Blue shale	28	2,504

Log of Blanchard No. 1 Surrey.

(Record received from A. G. Curtis.)

	Thickness Feet	Depth Feet
Sand and red clay	63	63
Shales and rocks	117	180
Gumbo and rocks	30	210
Gumbo and shale	30	240
Shale	20	260
Shale and gumbo	80	340
Shale	60	400
Rock at		400
Shale	20	420
Shale, gumbo, rocks	40	460
Shale and rock	115	575
Shale	95	670
White formation	80	1,420
White tough formation	50	1,470
Shale and shelly	80	1,550
Gumbo and shale—some gas	60	1,610
Gumbo	30	1,640
Gumbo and shale	40	1,680
Gumbo	30	1,710
Shale	40	1,750
Gumbo and shale	25	1,775
Sand rock	60	1,835

	Thickness Feet	Depth Feet
Rock, shelly	15	685
Shale	20	705
Gumbo	30	735
Shale	45	780
Gumbo	10	790
Shale	12	802
Rock	5	807
Gas rock	5	812
Shale	6	818
Shelly, gas from 820 to 845 feet	27	845
Rock	1	846
Shale	18	864
Sandy shale rock	2	866
Shale	54	920
Sandy shale	10	930
Gumbo	35	965
Hard shale	25	990
Gumbo	25	1,015
Shale	20	1,035
Gumbo, tough	40	1,075
Gumbo and shale	105	1,180
Shale	20	1,200
Gumbo and shale—turning white at base	60	1,260
White shale, shelly, with tough streaks and show of oil and gas	80	1,340
Gumbo with some gas	90	1,925
Gumbo	25	1,950
Sandy shale with hard streaks	25	1,975
Hard sandy shale	25	2,000
Hard sandy shale with streaks of gumbo	100	2,100
Shale	6	2,106
Gumbo	17	2,123
Blue shale	12	2,135
Gray shale (white)	9	2,144
Brown shale	4	2,148
Blue shale—gas rock last six feet	17	2,165
Blue shale, hard-white	6	2,184
Blue shale, gas rock	16	2,200
Soft brown shale	15	2,215
Hard shale	5	2,220
White shale	5	2,225
Dark shale	5	2,230
Red, brown and blue shale	13	2,243
Blue shale, sandy	7	2,250
Gray shale	4	2,254
Brown shale	1	2,255
Oil bearing beds	2.5	2,257.5

Log of C. G. O. Hostetter No. 1 Gas.

(Record received from B. G. Dawes.)

	Thickness Feet	Depth Feet
Brown and yellow clay	15	15
Gumbo and hard blue sale	11	26
Blue hard gumbo	64	375
Soft sand rock shell	2	377
Gumbo	45	422
Hard sand rock	3	425

	Thickness Feet	Depth Feet
Gray colored lime shale	2	28
Soft blue shale	24	52
Gray colored hard lime shell	1	53
Gumbo and soft blue shale	27	80
Gray hard lime shell	2	82
Soft blue shale	43	125
Gray hard lime shell	3	123
Gumbo, hard and stiff	32	160
Rock shell, sandy and soft	2	162
Gumbo, blue and hard	58	220
Sand rock, with gas	2	222
Stiff blue shale	58	280
Soft sand rock	3	283
Sandy brown shale, with gas	27	310
Hard sand rock	1	311
Hard tough gumbo	65	490
Soft sand rock	3	493
Gumbo and light blue shale	144	637
Kaolin, white shale, or gypsum	11	648
Soft sand rock (2.5 to 3 million gasser)	9	657
Kaolin or white shale, sandy at base	10	667
Hard stiff gumbo	91	758
Hard sand rock	3	761
Gumbo with sandy shale at base	16	777
Hard sandy shale	3	780
Caddo gas sand, quite hard, light in color, very sharp and gritty with some gas	3.5	783.5

Log of Broussard No. 1.

(Record received from B. G. Dawes.)

	Thickness Feet	Depth Feet
Joint and red clays	65	65
Water sand	7	72
Rock shell	2	74
Blue shale and gumbo, with rock shells	316	390
Hard dark shale with gas	15	405
in places—gas	95	1,893
Light shale	15	1,908
Big gumbo beads	62	1,970
Blue shale, hard at base	85	2,055
Kaolin shale to light shale, hard	15	2,070
Hard kaolin shale	12	2,082

	Thickness Feet	Depth Feet
Blue shale and brittle gumbo, with kaolin and shale at base	342	747
Caddo gas sand, broken with shale-gas	98	845
Hard shale and gumbo	15	860
Broken formation with coarse salt water, gravel at base	25	885
Blue shale, hard, with rock shells and gumbo	120	1,005
Kaolin shale beads then blue shale	170	1,175
Kaolin shales, with some blue shale and sand — gas and oil from 1,360 to 1.520 feet	360	1,535
Bastard lime and kaolin shale	85	1,620
Blue hard shale	30	1,650
Blue shale and gumbo	50	1,700
Blue shale turning to soft brown shale	98	1,798
Bastard lime rock, with sandy shale		
Kaolin and sandy shale, with gas	18	2,100
Broken hard sand rock with sandy shale layers	12	2,112
Dark sandy shale with oil and gas.	18	2,130
Loose soft blue shale	5	2,135
Hard rock	1	2,136
Sandy shale, with kaolin and a little pyrite, hard at base—gas and oil	38	2,174
Sandy shale with oil	23	2,197
Fine sand with oil.	3	2,200
Sandy shale, red at base	3	2,203
Red shale, turning light	15	2,218
Mixed blue and red shale	6	2,224
Blue shale, red shale and sand	4	2,228
Blue shale, sandy at base	7	2,235
Sandy shale, with oil	2	2,237
Mixed oil sand and dark shale, hard, good oil showing.	2	2,239

Log of Well Northwest of Plain Dealing, La.

(Record received from G. E. Gilmer.)

	Thickness Feet	Depth Feet
Red clay	40	40
Lignite	2	42
Yellow water sand	10	52
Clay	8	60
White water sand (artesian)	140	200
Sandstone rock	2	202
Black packed sand	493	695
Shale	300	995
Rotten shale and shells	200	1,195
Tough blue gumbo	420	1,615
White chalky rock, hard, with gas	8	1,623
Lime rock, with beds of sandy shale	364	1,987
Salt water sand, with gas	110	2,097
Sandy shale with oil	106	2,203
Rotten shells	20	2,223
Rotten shale with shells	260	2,483
White chalky rock	45	2,528
Shale	4	2,532
White hard chalky rock	4	2,536
Rotten shale with shells	114	2,650
Shells	10	2,660
Rotten shale with shells	17	2,677
Rock	29	2,706

Gas found at 390, 1,220, 1,628, 2,000 and 2,700 feet.

Oil found at 1,220, 1,630, 2,150 and 2,700 feet.

Log of C. G. O. Noel No. 2, Mooringsport.

(Record received from S. S. Hunter.)

	Thickness Feet	Depth Feet
Red clay	20	20
Water sand	15	35
Blue sand	15	50
Blue shale	35	85
Rock	1	86
Blue shale	19	105
Rock	1	106
Shale	69	175
Rock	1	176
Blue shale	345	521
Rock	1	522
Gumbo	389	911
Gas sand, with gas	19	930
Salt water sand	8	938
Gumbo and shale	562	1,500
White sand	45	1,545
Rock	1	1,546
Gumbo	57	1,603
Rock	8	1,611
Gumbo and shale	107	1,718
Gumbo, hard	217	1,935
Rock	1	1,936
Salt water sand	14	1,950
Gumbo and shale	71	2,021
Rock	2	2,023
Salt water sand with gas	12	2,035
White shale	429	2,464

ALPHABETICAL LIST OF THE WELLS IN AND ABOUT THE CADDO WITH DATA CONCERNING EACH.*

Arnell and Lee No. 1.
See Lee and Arnell No. 1.

Augur and Henderson Well near Shreveport.
See Henderson and Augur Well.

Alday and Daniel No. 1.
See Daniel and Alday No. 1.

Barnhart No. 1. McGuire. NW, NW, NW, Sect. 21-20-15.
Began drilling April, 1907. A 15,000,000 gasser at 812 feet June 5, 1907. Well capped.

Barnhart No. 2. McGuire. NE, NE, NW, Sect. 21-20-15.
Began drilling June, 1907. A 15,000,000 gasser at 795 feet June 5, 1907. Well capped.

Belcher. A well was to be drilled here 17 miles north of Shreveport, February 3, 1907.

Benedum & Tree No. 1. On the J. Stiles.
Derrick up Oct. 6, 1908. Drilling Oct. 20-Nov. 20, 1908.

Big Four No. 1. NW, SE, Sect. 1-20-16.
Rig up Feb. 3, 1907. Down 1,560 feet June 5, 1907. Produced 500-600 barrels of oil which has to be treated. Also called McCormick No. 1 on the Guy 5 acres. Well was being cleaned Aug. 6, 1908.

Big Four No. 2. S, NW, SE, Sect. 1-20-16.
Drilled to 2,240 feet by Del Southerland. Had a good showing of oil at 1,580 feet. A good producer. Well being cleaned Jan. 10, 1909.

Black Bayou No. 1. Alexander. SE, SE, Sect. 9-20-15.
Derrick up Oct. 20, 1908. Drilling Nov. 6, 1908, to Jan. 20, 1909. Completed Jan. 20, 1909—a 125-bbl. well.

Black Bayou No. 1. Glassell. SW, Sect. 10.
Drilling from June 10, 1908, to Oct. 6, 1908. Completed Oct. 6, 1908—a 300-bbl. well.

Blanchard No. 1. Surrey. NW, NW, SE, Sect. 12-20-16.
Formerly called Offenhauser No. 4. Drilling from Oct. 8, 1907, to Feb., 1908.

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*Corrections and additions to the above data will be gladly received. Information, to Feb. 15, 1909.

Blanchard No. 2. Surrey. NE, NW, SE, Sect. 12-20-16.
Completed July 6, 1908—a 100-bbl. well.

Blanchard No. 3. Surrey. S, SW, SE, Sect. 12-20-16.
Derrick up Sept. 20, 1908. Drilling from Oct. 6, 1908, to date. The well was shut down through November and part of December and January, 1909.

Blanchard No. 4. Surrey. NE, NE, SW, Sect. 12-20-16.
A derrick only.

Blanchard No. 1. Graham. Sect. 35.
Completed July 6, 1908. A dry hole at 2,504 feet.

Bossier City, Shreveport Well.
A water well owned by the Shreveport Cottonwood Co., struck gas at 500 feet and will drill deeper in search of oil.

Broussard No. 1. Brown. NE, NE, SW, SW, Sect. 18-20-15.
Drilling from Jan. 1, 1909, to date. Also called B. G. Dawes and others No. 1 Brown.

Broussard No. 1. Fee. SE, SW, SW, SW, Sect. 6-20-15.
Owner, B. G. Dawes. Congressman Oil Co. Drilling from June 1, 1908, to Aug. 1, 1908. Completed Aug. 1, 1908—a 100-bbl. producer. McCann & Harper, contractors.

Broussard No. 2. Fee. SE, SE, SW, SW, Sect. 6-20-15.
Drilled in clear lake bottoms. A hundred-barrel producer. Harper, driller.

Brown No. 1. S, NE, NW, NW, SW, Sect. 1-20-16.
Twisted off at 1,440 feet. Hole still remains 50 feet north of Hunter No. 1.

Brown Brothers No. 1. NW, SW, SE, Sect. 1-20-16.
Oil at 900-1,000 feet, heavy. At 1,300 feet the same oil was found as in the old Morrical-Savage well, July 3, 1905, completed at 1,560 feet, a 3 to 4 barrel well, Nov. 3, 1905. Afterwards made a 4 million gasser, Jan. 3, 1906. Owner, S. A. Nunnelley. Gas still being used Feb. 10, 1909.

Busch-Everett No. 1. Douglas. SW, Sect. 30-20-14. Dixie, La.
Drilling Jan. 20, 1909, to date.

Byron No. 1. McGuire. NE, SE, Sect. 17-20-15.
Equals old McGuire No. 1, his first well. A 20 million gasser at 802 feet.

(*Caddo Gas and Oil Co. will be abbreviated to C. G. O.*)

C. G. O. Black Diamond No. 1, Black Diamond, Ark. Drilling from June to October 1, 1907. A dry hole at 1,800 feet. C. E. Latham, driller.

C. G. O. Caddo Lake Oil and Pipe Line Co. No. 1. SW, SW, Sect. 1-20-16. Quoted as C. G. O. Smith No. 6 in the Oil Investors' Journal. Derrick April 19, 1908. Drilling from July 20, to Dec. 20, 1908. A 2500-bbl. well from the 1,580 feet stratum, gravity 30 degrees Baume. The best well in the field.

C. G. O. Caddo Lake Oil and Pipe Line No. 2. SW, SW, Sect. 1-20-16. Drilling from Dec. 17, 1908, to date.

C. G. O. Caddo Lake Oil and Pipe Line No. 3. SW, SW, Sec. 1-20-16. Derrick up Dec. 20, 1908.

C. G. O. Mary L. Cook No. 1. SW, Sect. 32. Began drilling Feb. 6, 1908.

C. G. O. Croom Club House No. 1, SE, NE, NW, NE, Sect. 35-19-16. Drilling from Jan. 3 to Jan. 15, 1907. A gas well at 820 feet. C. E. Latham, driller. Is at present being deepened.

C. G. O. No. 1 at Dixie, La. Drilling from Jan. 6, 1909, to date.

C. G. O. Donnell No. 1. State Line Well, Texas, La. Due west of Vivian. Derrick up June 6, 1908. Drilling from July 20 to Oct. 6, 1908. Shut down at 1,175 feet, waiting for further orders. C. E. Latham, driller.

C. G. O. Draper No. 1 at Draper, Texas. Began drilling March 7, 1907. Completed in June, 1907, a dry hole.

C. G. O. Fee Simple. Sect. 1-20-16. Rig up May 5, 1908—a 200-bbl. well May, 1908.

C. G. O. Gilbert No. 1 (*oil*), NW, NE, NE, Sect. 13-20-16. Drilling July 20 to Sept. 6, 1908. Completed Sept. 6, 1908—a 400-bbl. well. Gravity of oil 43 degrees Baume.

C. G. O. Gilbert No. 2 (*oil*).NE, NE, NE, Sect. 13-20-16. Began drilling Sept. 20, 1908. Completed Nov. 6, 1908—a 90-bbl. producer.

C. G. O. Gilbert No. 1 (*gas*). NE, NE, SE, Sect. 13-20-16. Formerly called Citizens' Oil and Pipe Line Co. No. 1 on the Gilbert tract, just north of the Caddo Lake. A great blow-

out, dynamited Nov. 4, 1906, to no advantage. This well is known as the burning mud and oil geyser.

C. G. O. Gilbert No. 2 (*gas*). NW, NW, NE, Sect. 13-20-16. Drilling Oct. to Nov. 18, 1905. Completed Nov. 18, 1905, as a good gasser. This well was on the line to Shreveport Feb., 1906, but is not used at present.

C. G. O. Gilbert No. 3. SE, NE, SE, Sect. 13-20-16. A good gasser, 1906, over which a new derrick has recently been built.

C. G. O. Gilbert No. 4. SE, SE, SE, Sect. 13-20-16. Began drilling Oct. 12, 1906, completed in Nov., 1906, a good gasser at 775 feet. C. E. Latham, driller.

C. G. O. Gilbert No. 5. NE, NE, NE, Sect. 13-20-16. Also called the Henning well—a gas well.

C. G. O. Glassell No. 1. SW, SE, Sect. 10-20-15. Drilling from Jan. 6, 1909, to date.

C. G. O. Harris No. 1, NW, SW, SW, Sect. 29-19-15. Derrick up Dec. 1, 1908, completed Dec. 17, 1908; a dry gasser, from the 800 stratum.

C. G. O. Hiner No. 1, at Vivian, La. NW, SE, SE, Sect. 26-22-16. Began drilling July 20, 1908, completed Sept. 10, 1908; a dry hole. Drillers, C. E. Latham and J. E. Todd.

C. G. O. Hostetter No. 1. Began drilling Jan. 7, 1907; completed Jan. 19, 1907; a 15-million gasser at 783 feet. W. H. Harper, driller. This well was turned in the gas line to Shreveport for a five-day test. It supplied Shreveport through 22 miles of 6-inch pipe and held a line pressure of 245 pounds at the Shreveport regulator station.

C. G. O. Hostetter No. 3. Began drilling, Dec. 21, 1907; completed Jan. 4, 1908; a 7-million gasser at 780 feet. On a three-minute test it held a rock pressure of 300 pounds. The gas is dry and clean. Is at present on the Shreveport line as in No. 1 above.

C. G. O. Hostetter No. 4. Began drilling Jan. 21, 1908; completed Feb. 11, 1908; a good gasser, at present on the Shreveport line. The depth of the well is 778 feet. This well was bailed at a depth of 777 feet and developed a volume capacity of 6.5 million cubic feet per day, and a rock pressure of 265 pounds on a two-minute test. The gas was

dry and clean. The well when shot in developed a peculiar phenomenon: The gas working back of the 8″, and coming up to the bottom of the 10″, only 83 ft. 9 in. from the surface; but the 10″ pipe having been successfully cemented, the escape of the gas in this way was cut off. However, the gas within twelve hours from the time the well had been shut in, worked through crevices in the rock shell on which the 10″ pipe had been set, and came up in a channel of Caddo Lake, extending out as far as one-half mile from the well. The surface of the lake had the appearance of a violent storm—the escaping gas blowing the water as high as 20 feet in places, but as soon as the well was opened up the gas came back through the 8″ and the escape by way of the lake ceased. The well was at once lubricated and killed by pumping it full of mud. The 8″ was pulled and a well packer set 65 feet from the bottom, and the casing then reduced to 6″; then a string of 8″ pipe was washed over the 6″ to the well packer. As the 8″ was withdrawn, the well was filled in back of the 6″ with concrete to the top of the ground. After allowing it to set for three days the well was again baled in and allowed to blow open for seven days to let the concrete set thoroughly. The well when shut in was in good shape, and no further escape of gas occurred. After standing for a few days it was connected in the line to Shreveport, and is now supplying the latter city (Jan. 1, 1909.) with gas. J. M. Guffey Pet. Co. and S. S. Hunter, owners; W. H. Harper, contractor; J. B. McCann, agent.

C. G. O. Hunter No. 1. E. NW, SW, Sect. 1-20-16. The first shallow well, about 1,580 feet deep; a 300-barrel well.

C. G. O. Hunter No. 2. S. NW, SW, Sect. 1-20-16. Began drilling Nov. 20, 1908; completed Jan. 20, 1909; a 65-barrel well.

C. G. O. Leary No. 1, at Leary, Tex., on the Midden farm. Began drilling Oct. 22, 1907; completed March 7, 1908; a dry hole at 1,800 feet.

C. G. O. McDowell No. 1. Completed June 20, 1908; a dry hole; may drill deeper. This well was abandoned after a blowout, June 20, 1908.

C. G. O. McDowell No. 2. Completed Aug. 20, 1908; a dry hole; may drill deeper.

C. G. O. Noel No. 1. NE, NW, SE, NW, Sect. 1-19-16. A gas well, capped.

C. G. O. Noel No. 2. S, NW, NW, Sect. 1-19-16. Completed at 2,460 feet; a dry hole.

C. G. O. Noel No. 3. NW, NW, SE, NW, Sect. 1-19-16. Completed in December, 1906; a gas well at 860 feet.

C. G. O. Offenhauser No. 1. NE, SE, Sect. 1-20-16. Formerly called Caddo Oil and Mining Co., Hunter & Hughes No. 1. Completed June 5, 1907; a 150-barrel well with some gas, at 2,170 feet. A small derrick was used in drilling this well. The well is not producing now.

C. G. O. Offenhauser No. 2. NE, SW, Sect. 1-20-16. Formerly called Citizens' Oil and Pipe Line Co. No. 2, or the Hughes-Offenhauser well. Completed May 1, 1908; a 250-barrel well.

C. G. O. Offenhauser No. 3. SE, NE, SW, Sect. 1-20-16. Formerly called Thompson No. 1. Rig up May 5, 1908. Began drilling May 19, 1908; completed Oct. 20, 1908; a 75-barrel well.

C. G. O. Offenhauser No. 4. NW, NE, SW, Sect. 1-20-16. Formerly called the Thompson No. 2. Drilling July, 1908; at present a small producer.

C. G. O. Pardue No. 1, at Vivian, La. SW, NW, Sect. 1-21-16. Completed Dec. 6, 1908; a 2½-million gasser.

C. G. O. Smith No. 1. SE, SE, Sect. 1-20-16. Formerly called the McCormick gas well. A gasser from 800-foot stratum.

C. G. O. Smith No. 2. NE, SE, SW, Sect. 1-20-16. Formerly called the Baby well. At 1,050 feet the well was bailed January, 1905, and developed salt water, flowing 80 feet above the derrick. After 203 days' flow it developed pure gas, and is at present a small gasser.

C. G. O. Smith No. 3. N, SE, SW, Sect. 1-20-16. Began drilling June 7, 1907; completed Oct. 2, 1907. After setting the strainer a big salt water well with gas and oil developed. On trying to pull the strainer the same became choked and blew out. The well flowed for several days, a 15-barrel well with much salt water, but drowned out in

ten days. In setting the 4″ pipe, the same parted at a collar when 100 feet from the bottom because of a defective joint under the elevator, completely plugging the hole. All the pipe but 150 feet was fished out and the whole was abandoned June 1, 1908.

C. G. O. Smith No. 4. SW, SE, SW, Sect. 1-20-16. Began drilling Nov. 28, 1907; completed Feb. 28, 1908, when the well was bailed in and developed from the deep sand a 500-barrel well. The oil was dark green in color and of 28.4 degrees Baume gravity at 60 degrees Fahr. This well was the best in the field when completed. The well was cleaned out Sept. 6, 1908, and is still a good producer.

C. G. O. Smith No. 5. SW, SE, SW, Sect. 1-20-16. Began drilling March 7, 1908; completed May 20, 1908, at 2,280 feet. Salt water drowned the well; 17 feet of cement was put in the bottom without effect. The well is not producing now.

C. G. O. Smith No. 6. NW, NE, SE, SW, Sect. 1-20-16. A derrick only.

Caddo Lake Oil and Pipe Line No. 1. Formerly called Savage Brothers and Morrical. This is the oldest well in the field. Rig up May, 1904; began drilling in June, 1904. A partial log is as follows: Lignite at 16 feet; rock, gravel and boulders to 300 feet; a good fresh water well at 85 feet; gas sand at 900 feet; 6″ set at 1,400 feet; stopped drilling at 1,556 feet in cream-colored shale with pyrite, April 3, 1905. The well was bailed March 28, 1905, a five-barrel well; deepened in July, 1905; idle November, 1905; gasser Jan. 3, 1906; oozed oil of 34.7 gravity Baume August, 1906, but not in paying quantities. Well was abandoned June, 1907.

Caddo Lake Oil and Pipe Line Co. No. 2. A new well was started south of No. 1, May 18, 1905. A heavy gravity oil was found at 950 feet, down 1,035 feet in shale Jan. 3, 1906.

Caddo Lake oil and Refining Co. In this well rock was struck at 1,400 feet; oil at 1,5546 feet, of 35 degrees Baume. The oil came to within 700 feet of the surface Feb. 3, 1905.

Caddo Oil and Mining Co. Rig up Sept. 19, 1907.

Citizens' Oil and Pipe Line Co. S, SE, Sect. 8-19-16. Also called Jeter well.

Cooper and Heard No. 1. Cooper, Winfield, La. Drilling from Dec. 20, 1908, to date.

Crawford No. 1. McGuire. SW, SW, NE, SW,, Sect. 17-20-15. A 15-million gas well.

Culliman and Jolly No. 1. NW, SE, SW, Sect. 18-20-15. Completed Dec. 18, 1906; a 15-million gasser at 110 feet; now owned by the Louisiana Oil Co.

Daniel and Alday No. 1. SW, SE, NW, Sect. 31-21-15. Blew out gas and salt water and is not now a producer.

C. G. Dawes Trustee No. 1. SE, NE, SW, Sect. 7-20-15. Began drilling March 17, 1908, but was lost before being finished. On the night of May 11, 1908, during a heavy rain storm, while putting back the 4″ rotary pipe, and when about 350 feet from the bottom the well blew out from the gas stratum between 1,360 and 1,420 feet, making 40 million cubic feet of gas per day under very high pressure, and showing a small amount of salt water. While preparing to lubricate and kill the well, the derrick was completedly destroyed by a cyclone on the evening of May 13th. Deeper gas worked out through the 8¼-inch casing in a defective seam or joint or under the bottom, and started the 800-foot or Caddo gas stratum to blowing out. It in turn worked through a split in the 10″ pipe 20 feet below the surface and blew out a very large hole about 20 feet deep, around the top of the 10″ pipe. After several days, the drillers succeeded in getting a joint of 14″ over the 10″ and in concreting a shoulder on the bottom of the 14″ to the 10″. Then they built a concrete anchor to the 14″, hoping in this way to be able to hold the gas long enough to lubricate and kill the well by pumping it full of mud. But the gas caught fire and burned from June, 1908, till the night of Feb. 12, 1909. The gas was lighted the next morning, but went out again within five minutes. Some salt water appeared, and with the gas forms a spray that still rises above the old hole. This well is the one which has been noted as the *burning gas well.*

C. G. Dawes Trustee No. 2. SE, SE, NE, SW, Sect. 7-20-15. Began drilling June 22, 1908; completed August, 1908; a

10 to 15-barrel well, with much salt water. At present not producing.

B. G. Dawes and C. G. O. No. 1. Christian, at Vivian, La. A location only.

B. G. Dawes and Gulf Refining Co. Heilperin No. 1. NW, SE, NW, Sect. 31-22-15. Began drilling Sept. 29, 1908; completed Oct. 22, 1908; a 15-million gasser. S. B. Clement, driller.

B. G. Dawes and Gulf Refining Co. Posey No. 1. SE, NE, NW, Sect. 25-22-16. Began drilling Sept. 15, 1908; completed Oct. 28, 1908; a dry hole.

Dawes No. 1. J. W. White. Rig up July 20, 1908; taken down since.

Dixie Oil and Pipe Line Co. No. 1. A 2,250-foot well; abandoned Sept. 19, 1907.

Dixie No. 2. Glassell. SE, Sect. 36, 5½ miles east of Mooringsport; a gasser Sept. 19, 1907.

Dixon Oil and Pipe Line Co. Sect. 22-20-15, four miles east of Mooringsport. Gumbo at 875 feet, shale and sand at 2,025 feet.

Dixon Oil and Pipe Line Co. No. 1. NW, SW, NW, Sect. 33-21-15. On Pine Island one-half mile east of Texla No. 1. A blowout occurred at 2,165 feet; killed and deepened to 2,500 feet. Casing pulled out June 19, 1907.

Dixon Oil and Pipe Line Co. No. 2. NW, NW, SW, Sect. 33-21, 15. Completed as a gasser at 840 feet, about 1.2 million capacity, March 19, 1907.

Enterprise No. 1. Noel. Sect. 12-20-16. Completed June 19, 1908. A fairly good producer.

Enterprise No. 2. Noel. Sect. 12-20-16. Completed Sept. 6, 1908; a 10-barrel well, 70 barrels gross.

Enterprise No. 3. Noel. NE, SW, NW, NE, Sect. 12-20-16. A derrick only.

Evans No. 1. McGuire. SE, NE, SE, SW, Sect. 18-20-15. A 15-million gasser at 812 feet, June 5, 1907.

Evans No. 2. McGuire. E, SE, SE, NW, Sect. 18-20-15. A 15-million gasser, 2,000 feet north of Evans No. 1, June 5, 1907.

Evans No. 3. McGuire. NE, NW, NE, SE, Sect. 18-20-15. A good gasser, June 5, 1907.

Filer No. 1. NE, NW, NW, SE, Sect. 7-20-15. Completed July 28, 1908; a 140-barrel well, now producing very little.

Filer No. 2, just SE of the center of Sect. 7-20-15. Derrick up July 20, 1908; completed Nov. 6, 1908; a 30-barrel well.

Filer No. 3, or 1-18. S, NW, NW, NE, Sect. 18-20-15. Completed Feb. 6, 1909; a 100-barrel well.

Gulf-Broussard No. 1. Pitts. Sect. 20-20-15. Began drilling Feb. 6, 1909.

Gulf Refining Co. No. 1. Christian. NE, SW, SW, Sect. 30-20-15. Rig up Feb. 6, 1909.

Guffey-Christian No. 1. Sect. 31. Derrick up May 5, 1908; blown over by a high wind and site abandoned.

Gulf Refining Co. No. 1. Curtis. N, NE, SE, Sect. 19-20-15. Derrick up Jan. 1, 1909; began drilling, Feb. 6, 1909.

Guffey No. 1. Dixon Farm. NW, Sect. 33-20-15. On Pine Island; down 2,200 feet June 5, 1907.

Gulf Refining Co. No. 1. Edwards. NE, Sect. 31-20-15. Began drilling Feb. 6, 1909.

Gulf Refining Co. No. 1. J. Harris. Sect. 32-19-15. Began drilling Jan. 6, 1909.

Guffey-Hostetter No. 1. SE, Sect. ————. Began drilling Jan. 22, 1907; March 19, 1907, the well blew out at 2,208 feet, with 613 feet of 8-inch casing in the hole. When 2,209 feet was reached, the well was shut down and preparations were made to set the 6-inch, but as soon as the pump pressure was shut off the well at once blew out, and at the time having only 613 feet of 8-inch casing in the hole, was completely destroyed by the terrific gas pressure, the well developing a rock pressure of close to 1,000 pounds. After blowing out for three days, deep gas stratum was choked off by the collapsing of the 4-inch rotary pipe and caving of the shales. The well was then coffer-dammed around the 8-inch to a depth of 29 feet on top of the first rock stratum, and after driving a string of 12-inch pipe around the 8-inch, it was then concreted to the top of the ground and in this way the well was shut in finally, and the blowout stopped. This well when the gate was opened during the fall of 1908, began to flow and averaged from 10 to 30 barrels of high-grade oil per day for several months.

but finally stopped flowing when a well was brought in near by.

Guffey-Hostetter No. 2. Began drilling June, 1908; completed Dec. 8, 1908. A 300-barrel well. This well was claimed to be making 10,000 barrels when first completed, and caused a great stir in the field, but later reports show that its average capacity is nearer 200 barrels.

Gulf Refining Co. No. 3. Hostetter. Began drilling Feb. 6, 1909.

Gulf Refining Co. No. 1. Mason. Began drilling Feb. 6, 1909.

Gulf Refining Co. No. 2. Mason. Derrick up Jan. 6, 1909.

Gulf Refining Co. No. 1. Nunnelley. Derrick up December, 1908; began drilling January, 1909.

Guffey-Pitt No. 1. NW, NW, NW, Sect. 7-20-15. Derrick up July 3, 1905; now abandoned.

Gulf Refining Co. No. 1. Sorelle. SW, Sect. 30-20-15. Drilling January, 1909.

Hastings Oil Co. Rig up June 18, 1905.

Henderson and Augur well, near Shreveport, on Douglas Island. Abandoned at 2,250 feet Dec. 3, 1905. This well produces some salt water and gas; shoots ten feet in the air and the gas when lighted will burn for a short time, but soon goes out.

Heywood No. 1. Fee. NW, NW, SW, SE, Sect. 1-20-16. Began drilling, September, 1908; completed December, 1908; a dry hole at 2,257 feet. H. Jones, driller.

Heywood No. 1. Savage. SE, SE, NE, SE, Sect. 2-20-16. Drilling from December, 1908, to February, 1909; a dry hole, with show of oil in the 1,500-foot stratum.

Huckaby No. 1. McGuire. SE, SW, SW, Sect. 17-20-15. A 25-million gasser at 823 feet, June 5, 1907.

Jolly No. 1. See Cullinan and Jolly No. 1.

Jolly No. 2. NW, NE, SW, SW, Sect. 17-20-15. A gas well drilled in 1907, now owned by Louisiana Gas Co.

Latex Oil and Pipe Line Co. No. 1. SW, SW, SW, Sect. 3-20-16. Twisted off at 800 feet, but found traces of oil July 18, 1905.

Latex Oil and Pipe Line Co. No. 2. S, SW, SW, Sect. 3-20-16. The third well drilled in the field, not producing now.

Lee and Arnett No. 1. Sect. 10-18-14. Began drilling in December, 1905; struck gas stratum at 975 feet, June 3, 1906.

This well is located three miles northwest of Shreveport and is not producing now.

Lee and Arnett No. 2. This well is located 900 feet west of No. 1, and struck gas at about the same depth; not producing now.

J. A. Libby. Had a derrick up on the S. A. Guy 30-acre tract June 18, 1905.

Lillie No. 1. N, NW, NW, Sect. 12-20-16. Completed June, 1908; a 100-barrel well, a fairly good producer.

Lillie No. 2. NW, NW, NW, Sect. 12, 20-16. Derrick up December, 1908; about Jan. 1, 1909, the hole was lost at 1,440 feet.

Lillie No. 2, second hole. This well is located about 10 feet north of the old Lillie No. 2, and is drilling (Feb. 6, 1909).

Lillie No. 3. Drilling Feb. 1, 1909.

Mansfield No. 1. NE, SE, SE, SE, Sect. 1-20,16. Began drilling December, 1908; completed February, 1909; a 125-barrel well.

Marshall Gas Co. No. 1. R. T. Cole, at Blanchard, La. Rig up Nov. 6, 1908; drilling from November. 1908, to date. This well and a half interest in the holdings of King Bros., the owners, were bought by Producers' Oil Co. The latter will drill to 1,500 feet or more. The well was down 1,100 feet in February, 1909.

Marshall Gas Co. No. 1, near Blanchard. Derrick up September, 1908; the well was never drilled.

Marshall, Texas well on the Blocker place, 10 miles southeast of Marshall, Tex. This well was down 1,500 feet January, 1909, and is still drilling.

Maxwell and Hardy No. 1. See Texla No. 1.

McCann and Harper No. 1. Pitts. NE, NW, Sect. 31-22-15. Drilling February, 1909.

McCormick No. 1. Croom. Derrick up Sept. 14, 1908; well completed February, 1909; a 50-barrel well. Driller, Del Southerland.

McCormick No. 1, Mooringsport. All traces of this derrick have been removed. The derrick was blown over by a strong wind and the site abandoned.

McCormick No. 2, Mooringsport. Also called Thompson No. 1. This derrick was also destroyed by a strong wind, and this site abandoned.

McCormick No. 1, Shreveport. Also called the Brickyard well. This well was drilled in the winter of 1904-5 and is the second oldest well in the field. It was drilled to 1,650 feet in search of gas as fuel for burning brick. At 910 feet there was a show of gas, but salt water spoiled all chances of obtaining a good well at this depth. The well was later drilled to a depth of 2,000 feet, but no oil was obtained.

McGuire Wells. See under the names of the individual wells.

Merchant No. 1. NE, NE, SW, SW, Sect. 6-20-15. Derrick up Dec. 25, 1908; drilling February, 1909.

Nichols Oil and Gas Co. No. 1, north of Paraloma, Ark. Began drilling August, 1908; down 535 feet Dec. 14, 1908. Driller, R. H. Ferguson, Milford, Ark.

Producer's Black Bayou No. 1. SE, NE, SE, SE, Sect. 7-20-15. Derrick up July 19, 1907; completed November, 1907; a 100-barrel, producer, but the oil has to be cooked. This well had an initial capacity of 700 barrels.

Producer's Black Bayou No. 2. W, SE, SE, Sect. 7-20-15. Drilling from April to August, 1908; completed; a 50-barrel well with considerable gas.

Producer's Black Bayou No. 3. W, SW, NE, Sect. 18-20-15. Derrick up October, 1908; completed Dec. 7, 1908; a 90-barrel producer. The gravity of the oil in this well is 37.3 degrees Baume.

Producer No. 1. NW, SW, SE, Sect. 1-20-16. This well was a good gasser at 812 feet, but blew out and is now a large salt water blower.

Producer No. 2, C. O. and Min. Gas was struck in this well at 750 to 850 feet. The well was completed at 830 feet, but a blowout occurred, which blew sand and mud all over the derrick, April 13, 1905.

Producer No. 3, C. O. and Min. Drilling from June to July, 1905. A blowout occurred also in this well and the well was lost.

Producer's No. 4, C. O. and Min. This well was put down to kill the two blowouts, No. 3 and No. 4, on the Caddo Oil

and Mining lease. The well was completed March 9, 1906; a small gasser at 842 feet. When this well was brought in, the two geysers ceased to remain active, and their sites are now marked by salt lakes.

Producer's No. 5, C. O. and Min. SW, NE, Sect. 12-20-16. This well is 2,000 feet south of No. 2. Rock was struck at 185 feet, sand and shale at 1,650 feet, and at 2,180 feet there was a strong gas pressure developed. The well was completed, a 190-barrel producer, Aug. 5, 1907.

Producer's No. 6, C. O. and Min. Commenced drilling Nov. 5, 1907; completed June 19, 1908; a 50-barrell well.

Producer's No. 7, C. O. and Min. Began drilling in April, 1908; completed June 19, 1908; a 100-barrel well.

Producer's No. 8, C. O. and Min. A derrick only.

Producer's No. 1. Evans. SE, SE, NE, Sect. 11-20-16. Completed April, 1908; a 35-barrel well, which has since turned mostly to gas.

Producer's No. 1. Fee. NE, Sect. 30-20-15. Mooringsport. Began drilling Jan. 20, 1909.

Producer's No. 1. Harrell. SE, NE, SE, Sect. 30-21-15. On Pine Island, one mile northwest of Texla No. 1, on the Harrell 204-acre tract. Began drilling November, 1906; completed in June, 1907; a dry hole at 3,000 feet; since abandoned. This well is the deepest in the field.

Producer's No. 2. Harrell. NE, SE, Sect. 2-21-16. Began drilling July, 1908, and is still drilling.

Producer's No. 1. Heilperin and Liebman. SW, NE, SW, Sect. 31-21-15. On Pine Island; a 75-barrel well at 1,400 feet. (?) Deepened and producing 20 barrels February, 1908.

Producer's No. 2. Heilperin and Liebman. NE, SW, NE, SW, Sect. 31-21-15. On Pine Island, 500 feet north of No. 1; reported a producer at 1,400 feet. A blowout occurred at 2,154 feet. The well turned to a gasser in June, 1908.

Producer No. 1. J. W. Holt. SE, NE, SE, SE, Sect. 2-20-16. Began drilling December, 1908; completed in February, 1909; a dry hole.

Producer's No. 1. Homestead. Sect. 12-20-16. Began drilling February, 1908; completed May, 1908; a 100-barrel well.

Producer's No. 2. Homestead. S, SW, SE, SE, Sect. 12-20-16. Began drilling September, 1908; twisted off and abandoned.

Producer's No. 3. Homestead. SW, SE, SE, Sect. 12-20-16. Began drilling November, 1908, with the rig formerly used in drilling No. 2; completed Jan. 6, 1909; a 70-barrel well.

Producer's No. 1. Lane. Began drilling in June, 1908; completed September, 1908; a 400-barrel well.

Producer's No. 2. Lane. NW, NE, NW, Sect. 18-20-15. Began drilling June, 1908; completed October, 1908; a 300-barrel well. This well has been often reported to be making from 2,000 to 3,000 barrels, and probably is good for 500 barrels.

Producer's No. 3. Lane. SW, SE, NE, NW, Sect. 18-20-15. A derrick only, Dec. 15, 1908.

Producer's No. 4. Lane. SW, SW, NE, NW, Sect. 18-20-15. Began drilling December, 1908.

Producer's No. 1. Leonard. NW, NE, NW, NW, Sect. 6-20-15. On Pine Island. Began drilling February, 1907; a 9-million gasser at 2,128 feet, April, 1907

Producer's No. 1. J. Milam. SW, Sect. 9-19-15. Began drilling February, 1909.

Producer's No. 1. Murray. NW, NE, SE, Sect. 12-20-16. Began drilling October, 1907; completed January, 1908; a 100-barrel well.

Producer's No. 2. Murray. NE, NE, NE, SE, Sect. 12-20-16. Began drilling July, 1908; completed Feb. 6, 1909; a gasser.

Producer's No. 1. Murray, Colquitt and Hardy. NW, NW, Sect. 18-20-15. Began drilling September, 1908; completed December, 1908; a 125-barrel well.

Producer's No. 1. Richardson. NE, NW, NW, Sect. 12-20-16. Began drilling May, 1908; completed Aug. 20, 1908; a 50-barrel well.

Producer's No. 1. Ruddersdorf. NE, NE, NW, Sect. 11-20-16. Began drilling June, 1908; shut down since January, 1909. Well was never completed.

Reliance No. 1. SE, NW, NW, NW, Sect. 7-20-15. Formerly called Richardson No. 1; on the R. L. Pitts. Began drilling January, 1907; was a gasser from October to December, 1907, from the 2,200-foot stratum. A blowout occurred and at present the well is a salt water blower.

Reliance No. 2. NW, NW, Sect. 7-20-15. Began drilling Nov. 17, 1907; completed April 27, 1908. After bailing, while withdrawing the 2½-inch washpipe the well came in as a 25-million gasser. In the confusion the 2½-inch pipe fell in the hole; all was gotten out but the last five joints. When bailed in again, it came in as a 25-barrel well and a 15 to 20-million gasser. In a few days the gas decreased and the oil increased in volume, and on June 1, 1908, the well was making 12 to 15 million cubic feet of gas and 175 barrels of oil. It is still a good producer.

Reliance No. 3. Pitts. SW, NE, SW, NW, Sect. 7-20-15. Began drilling in December, 1908; completed February, 1909; 75 barrels.

Richardson No. 1. Pitts. See Reliance No. 1.

Richardson No. 2. Pitts. See Reliance No. 2.

D. C. Richardson No. 3. SW, SE, NE, NW, Sect. 32-20-15. On Pine Island, 600 feet northwest of Texla No. 1. Shale and sand at 1,820 feet; at 2,085 feet a blowout occurred, and on May 19, 1907, hole fell in 250 feet, and at present the well is a salt water blower with a depth of about 1,750 feet.

Richardson No. 4. SW, NE, NW, Sect. 32-20-15. Shale and sand, with oil, at 2,068 feet; a 300-barrel well, November, 1907.

Richardson No. 5. SE, SE, NE, NW, Sect. 32-20-15. Completed Oct. 25, 1908; a 3,900-barrel well. On October 27, 1908, it went to mud and sand, and then stopped producing.

Richardson No. 6, SW, SW, NE, NW, Sect. 32-20-15. A derrick only; on Pine Island.

Richardson No. 1. Guy. NE, Sect. 32-20-15. Drilling began in January, 1909.

Richardson No. 1. Nunnelley & Richardson. SE, SE, Sect. 25-21-16. Began drilling December, 1908.

Richardson No. 1. Richardson. SE, NW, SW, SW, Sect. 1-20-16. Began drilling December, 1908; a dry hole January, 1909. Shot with nitro-glycerine without effect.

Rogers No. 1. Rogers; at Lewis. Sect. 24-21-16. At 2,000 feet gas began to escape through the cracks in the ground and finally the derrick and all fell in. Estimated capacity 40

million cubic feet of gas in August, 1908. This well became a salt water blower, but was successfully killed by Brown Brothers, the drillers. In December, 1908, operations were commenced to go deeper.

Rogers No. 2. Rogers; at Lewis. Sect. 24-21-16. Began drilling July, 1908; completed Sept. 6, 1908; a big gasser (40 million cubic feet) at 1,035 feet.

Rogers No. 3. Rogers; at Lewis, La. SW, Sect. 24-21-16. Began drilling December, 1908.

Savage Brothers and Morrical. See Caddo Lake Oil and Pipe Line Co., ditto.

Savage and Richardson No. 1. One-quarter mile north of Savage Brothers and Morrical, in the northeast corner of Caddo town site. Thirty-eight feet of oil sand was struck at 2,280 feet; the oil was 27-degree gravity Baume. The well was pumped at the rate of 40 barrels and turned to salt water Nov. 18, 1906.

Savage and Richardson No. 2. Five hundred feet NW of Producer's No. 1, Heilerpin and Liebman; Nov. 18, 1906.

Savage No. 2. NW, NW, Sect. 1-20-16. Estimated at 2,200 feet, June 5, 1907.

School No. 1. McGuire. SW, SW, NW, SW, Sect. 16-20-15. A 20-million gasser at 805 feet, June 19, 1907.

School No. 2. McGuire. SE, SE, SW, NW, Sect. 16-20-15. A 20-million gasser at 825 feet, Aug. 19, 1907.

Shreveport Petroleum Co. No. 1. Fifteen hundred feet northwest of the center of Section 1, near Savage No. 2. Oil was found at 2,200 feet in June, 1907.

Staiti No. 1. SW, Sect. 31-20-15. Mooringsport, on the Ward tract. Began drilling February, 1909.

St. Louis and Southwestern Oil Co.; near Mooringsport. Twisted off at 800 feet, January, 1906.

St. Louis Oil and Pipe Line Co., south of Mooringsport. Down 900 feet and shut down.

Texla No. 1. NW, NE, SW, NE, Sect. 32-21-15. On Pine Island. The well that opened this district. A 275-barrel oil well, plus 20% of salt water, December, 1906. Slightly deepened, the well flowed by head 150-200 barrels 20 degree gravity

Beaume oil. The well was deepened to 2,264 feet and developed salt water. The casing was pulled August, 1907.

Texla No. 2. NW, SW, NE, Sect. 32-21-15. On Pine Island, within 300 feet of No. 1. Abandoned at 2,300 feet, June 5, 1907, because the well developed salt water. The casing was pulled and the hole was abandoned.

Texla No. 3. NE, SE, NW, Sect. 32-21-15. On Pine Island. Began drilling April, 1908; completed Aug. 20, 1908; 300 barrels net, with some salt water.

Thompson No. 1. See McCormick, ditto.

Trees and Benedum No. 1. See Benedum and Trees No. 1.

Trees No. 1. Dixon. Began drilling August, 1908; completed Nov. 6, 1908; a dry hole.

Trees No. 2. Dixon. Shut down through June and July, 1908, because of high water.

Trees No. 1. S. A. Guy. Derrick only.

Trees No. 1. Heilperin and Liebman. NE, NE, NW, Sect. 32-21-15. On Pine Island. Began drilling June, 1908; completed Nov. 6, 1908; a dry hole.

Trees No. 3. Ruddersdorfer. SE, SE, NE, Sect. 11-20-16 Derrick only.

J. C. Tree's Oil Co. No. 1. NW, Sect. 27-21-16. On the W. P. Stiles tract, west of Lewis Station. Brown Brothers, drillers. Completed Dec. 6, 1908; 50 barrels of oil with a large amount of gas at 1,069 feet; Jan. 20, 1909, the hole was deepened, and by pumping with a standard rig 300 barrels of oil and 300 barrels of water were produced daily. February, 1909, the daily capacity was stated to be 125 barrels. This well is the farthest west in the field.

Vivian Oil Co. No. 1. Childs. Owned by the Dawes Co. Began drilling in November, 1908; completed Dec. 18, 1908; a 75-barrel well with a small amount of water.

Vivian Oil Co. No. 1. Edwards. Owned by the Dawes Co.: began drilling in August, 1908; completed September, 1908; a 25-barrel well.

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